# APPLIED GEOCHEMISTRY: RECENT TRENDS AND ISSUES IN AFRICA (2012 - 2016)

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## Summary

This Report looks at the rate of application of Applied Geochemistry (AG) in Africa during the period 2012 to 2016. The assessment is based on the AG output volume of field and laboratory work, other research activities and publications. It is shown that despite a significant improvement during the period under review, much more large-scale and efficient application of modern AG methods and techniques is needed to address problems of pervasive air-, soil- and water pollution, including solid waste and mine water management, food security and climate change.

Table 1. Ranking Africa's recent (2012 - 2016) AG output (Based on Internet Search of 30.05.16)

| Rank | Area of Activity (Field campaigns; Research; Publications) | Output (%) | Remarks |
|---|---|---|---|
| 1 | Geochemistry and Health [Medical Geochemistry (MG)] | 67 | Ever since the inception of the International Medical Geology Association (IMGA) and formalization of the subject of MG in 2000, there has been an remarkable upsurge of research all around the continent |
| 2 | Chemistry and Pollution of Natural Waters | 6 | Proliferation of research on water quality is as a result of the realization by all stakeholders that climate change would exacerbate the already dire situation that currently exists |
| 3 | Air Quality Chemistry | 5 | Flurry of research effort in line with global activities in the area of atmospheric chemistry, to address climate change |
| 4 | Soil Pollution Chemistry/ Contaminated Land | 5 | Main sectors responsible for soil pollution in Africa are mining, agriculture and waste disposal; a huge research effort supported by international funding has been mounted to address this, through measures such as phytoremediation |
| 5 | Geochemistry in Agriculture | 4 | Research into chemical technology that would help African farmers improve yields gained impetus due to the urgent need to meet food security targets |
| 6 | Climate Change Chemistry | 4 | Flurry of activities in line with the |

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| | | | trend of research on global change phenomena |
| 7 | Geochemistry in Mineral Exploration (GME) | 3 | Numerous geochemical prospecting programmes were mounted or continued, largely by mining companies. However, many geochemical and mineral target maps that are generated are not put in the public domain, for reasons of confidentiality. This explains the unexpected low ranking of GME. The Africa Geochemical Database Project received a major boost in 2014, with the signing of an MOU between the Geological Society of Africa and UNESCO; and the launching of the International Centre for Global-Scale Geochemistry in China in May this year (2016) |
| 8 | Geochemistry in Waste Management [Including Mine Wastewaters (AMD)] | 2 | The geochemical aspects of hazardous and non-hazardous waste disposal in Africa remains poorly researched. This is apart from the subject of AMD, which continues to be of serious environmental concern, particularly in South Africa – one of few African countries with established institutional structures for articulating waste disposal policies |
| 9 | Isotope geochemistry | 1 | A significant rise in the use of chemostratigraphy and isotopic dating is realized, as researchers begin to appreciate the potential of both stable and radiogenic isotopes to provide answers beyond the reach of geology (e.g., See West et al., 2014) |
| 10 | Urban Geochemistry | 1 | Some data are available for the separate compartments of air, water and soil; but this area of AG research in Africa is still in its infancy (e.g., See Davies, 2015a) |
| 11 | Marine Geochemistry | 1 | The volume of research on marine geochemistry in Africa is very low. Surprisingly, little geochemistry is applied in exploration for offshore resources, despite the many discoveries made (e.g., East Africa) during the period under review. Among the most recent studies is the work of Compton and Bergh (2015) |
| 12 | Extraterrestrial Geochemistry | 1 | Volume of research on Extraterrestrial Geochemistry is low compared to work done in other continents. Among the more important of the recently published works are those of Nagaoka et al., 2013 and Simonson et al., 2015 |

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## I. Environmental Geochemistry and Health

The growing acceptance by the medical profession of the significance of factors of the geochemical environment in the aetiology of hitherto poorly diagnosed health conditions in major mining centres of Africa, has led to a considerable upsurge of research in the area of Medical Geochemistry (Table 1). These studies have been widely supported in recent years, thanks to a favourable shift in international funding policies. For example, results from the recently completed UNESCO/SIDA funded Projects on 'Environmental Health Impacts of Mining in Africa' (IGCP 594 and 606) produced a Special Issue of the Journal of Geochemical Exploration (Kribek et al., 2014, JGE, Vol. 144, Part C, 387 - 581), which, since its publication has been experiencing an extraordinary download rate.

Medical Geology is now a major theme in global environmental conferences, e.g., it will feature at the ISEH and ISEG Joint International Conference on Environment, Health, GIS and Agriculture in Galway, Ireland, 14 - 20 August, 2016 (http://www.nuigalway.ie/iseh2016/themes.html), and at the 35$^{th}$ International Geological Congress in Cape Town, South Africa, 27 August - 04 September, 2016 (www.35igc.org).

## II. Chemistry and Pollution of Natural Waters

Research on 'Water Chemistry and Pollution' continues to proliferate during the period under review, as we seek additional data on rainfall variability imposed by climate change. The results which also encapsulate future research needs, are articulated in numerous meetings and conferences.

In the 'British Geological Survey—Global Geoscience 2014 - 2015 Report', Dan Lapworth describes the work of a team from the University of Zambia, the University of Surrey and CEH working on a project (Urban groundwater quality in sub-Saharan Africa) to understand the processes that lead to groundwater contamination in growing urban towns in Africa, and the implications for health and livelihoods for the communities that rely on these resources for drinking water. The project is part of the UPGro Programme (see http:// www.nerc.ac.uk/research/funded/programmes/ upgro/), funded by NERC, ESRC and DfID. BGS has been involved in six UPGro projects carrying out groundwater studies across Africa.

Some of the major conferences lined up for the second half of 2016 include:

- AfricaEWRM 2016: The 6th IASTED African Conference on Environment and Water Resource Management, 5 - 7 September, 2016 in Gaborone, Botswana. http://www.iasted.org/conferences/

- Water Pollution 2016: 13th International Conference on Modelling,Monitoring and Management of Water Pollution, which will be held from 27 - 29 June 2016 in San Servolo, Venice, Italy. www.wessex.ac.uk/conferences/2016/water-pollution.

- The 35th International Geological Congress (Cape Town, South Africa) will no doubt discuss important results, as well as outline areas for future research on 'Water Chemistry and Pollution' under the major conference themes such as: Groundwater and Hydrogeology and Environmental Geosciences.

**III. Air Quality Chemistry**

Air pollution in African cities stems largely from sources that include particulates and smoke from fossil fuel combustion, vehicular emissions, roadside dust containing pathogens and indoor radon concentrations in ambient air.

Most of the recent air quality research is taking place in South Africa, which has a dedicated Department [the South African Air Quality Information System (SAAQIS)] that provides a common platform for managing air quality information in the Country.

The 2012 "State of the Air in South Africa" Report by the Department of Environmental Affairs concluded that " … air quality, especially in dense urban-industrial areas, remains a national cause for concern", but it is uncertain as to whether there has been an improvement over the last two to three years (e.g., Buthelezi and Davies, 2015).
The volume of air quality research in African megacities, pre-2012 (see e.g., Davies, 2015a; 2015b) appeared to have petered somewhat, and there is hardly any evidence that air pollution problems are reducing.

Recent and Forthcoming conferences

- The 16th International Union of Air Pollution Prevention and Environmental Protection Associations was held in Cape Town on 29 September - 04 October 2013, with the theme: "Many Nations - One Atmosphere: Plotting the Path to Sustainability". https://www.environment.gov.za/mediarelease/molewa_iuappa_congress (Accessed 31.05.16).
- The Department of Environmental Affairs (DEA) of South Africa will be hosting its 11th Annual Air Quality Governance Lekgotla from 03 - 04 October 2016 at Emnotweni Arena and Conference Centre in Nelspruit, Mpumalanga in South Africa. www.airqualitylekgotla.co.za/(Accessed 31.05.16).

**IV. Soil Pollution Chemistry/Contaminated Land**

Main sectors responsible for causing soil pollution include mining, agriculture and waste disposal. A huge research effort supported by international funding has been mounted to address this, through measures such as phytoremediation (e.g., See Kříbek et al., 2014; Arthur et al., 2015). The most active research groups in this domain, are in South Africa, where we find the most extensive areas of land contamination largely from mining.

Recent Conferences

- 7th International Conference of the African Soil Science Society, 25 October to 01 November 2015, Ouagadougou - Burkina Faso. Theme: Critical soil solutions for sustainable Development in Africa
- Urban Soils and Heavy Metal Contamination Conference 2016, 09 - 11 March 2016, Johannesburg, South Africa. Theme: Implementing Mobility Assessments & Risk Aversion Strategies for Heavy Metals

## V. Geochemistry in Agriculture

Understanding/integrating soil geochemical processes at multiple scales for agricultural and health purposes has not yet been achieved in Africa, due to data gaps and technical/analytical capacity constraints.

Several projects on 'Geochemistry in Agriculture' were started or completed during the period under review, all based on the premise that understanding soil geochemical processes is essential to support policies in agriculture (e.g. liming, organic residue incorporation) and public health (e.g. mineral deficiencies and toxicities); and that **c**ollaborations between scientists of different disciplines (including geochemistry), and in different countries, can lead to innovative solutions for improving agricultural productivity.

In September, 2012, the Pan Africa Chemistry Network (PACN) of the Royal Society of Chemistry (RSC)] released its Report on 'Increasing Africa's Agricultural Productivity', in which it re-iterated among other strategies, the need for coherent research across scientific disciplines to develop methodologies that work at the farm level.
At the Global Soil Week event in Berlin in 2013, researchers presented analytical tools, such as new spectroscopy techniques (Schiermeier, 2013) that permit rapid soil-fertility assessment through analyses of agricultural soil samples, and production of site-specific soil maps for farmers.

Round 1 of the Africa Capacity Building Initiative on "Strengthening African Capacity in Soil Geochemistry to Inform Agriculture and Health Policies", funded by the Royal Society's Department for International Development (Royal Society – DFID), runs from 2015 - 2020. The Project aims to increase knowledge, and strengthen capacity, in soil geochemistry in Malawi, Zambia and Zimbabwe. The Project team will undertake experimentation to better understand the biogeochemical controls on trace element mobility and their soil-to-crop transfer through improvement of soil analytical capabilities, soil geochemical mapping and predictive modelling.

Africa Soil Information Service (AfSIS)

The Africa Soil Information Service (AfSIS) Project (2009 - 2016) applies geostatistical methods to develop continent-wide digital soil maps for Africa by combining information from soil legacy data, new types of soil analysis and high-resolution gridded environmental covariates. AfSIS's maps (e.g., Fig. 1) are useful for providing of information that is needed to support initiatives to increase smallholder farm productivity, capacity development and more sustainable agriculture. A number of databases have been developed and extended to support the new data

collection efforts, new techniques in laboratory analysis, and continent-wide digital soil mapping undertaken by AfSIS.

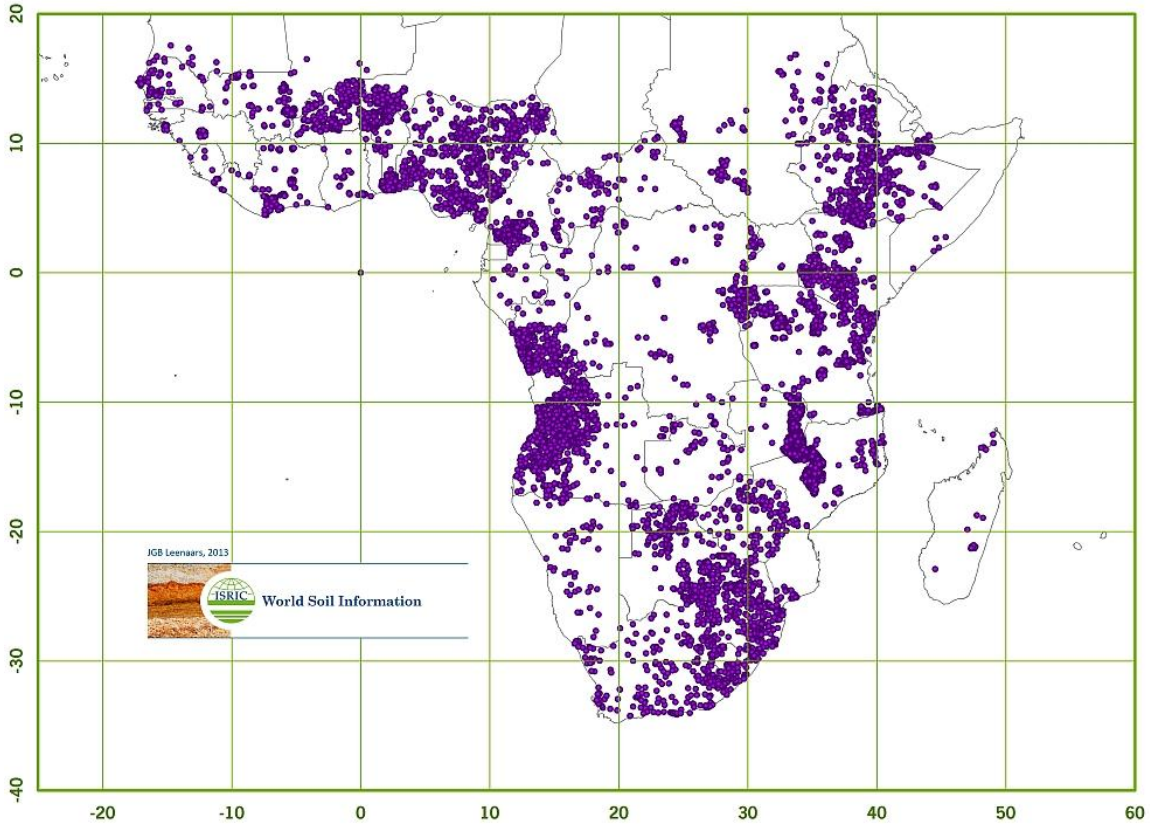


Fig. 1. Africa Soil Profiles Database. Source: http://www.isric.org/content/africa-soil-profiles-database-afsp (Accessed 01.06.16).

## VI. Climate Change Chemistry

The amount of research done in Africa on 'Climate Change Chemistry' has been limited during the period under review. Most of this research is done in conjunction with atmospheric and air quality studies (See Section III).

The last meeting in the "Climate Change and Development in Africa (CCDA) Conference Series" was convened at Victoria Falls, Zimbabwe from 28 - 30 October 2015. The 2015 conference theme was "Africa, climate change and sustainable development: what is at stake at Paris and beyond?".

The Series was conceived as an annual forum to enable linkages between climate science and development policy by promoting transparent discussions between key stakeholders in the climate and development community.

## VII. Geochemistry in Mineral Exploration

Several geochemical exploration programmes were started, or are ongoing, or were concluded during the period under review (1012 - 2016) in several countries, including: Zimbabwe, South Africa, Uganda, Sierra Leone, Kenya, Cameroon, Zambia, Mali, Tanzania, Ghana and the Democratic Republic of the Congo (DRC). However, these surveys were designed largely for the purpose of detecting anomalies at specific exploration prospects, for geothermal hotspots indentification, or other purposes. Thus, sampling densities and analytical protocols used often do not fall anywhere near those recommended in the Darnley et al. (1995) 'Global Geochemical Baselines Report,' and modified for use in tropical terrains.

### Use of Geochemistry in Oil and Gas Exploration

Despite the numerous discoveries of oil and gas both on- and offshore Africa (e.g., East Africa), little use is made of well and surface geochemistry in exploration ventures, with most drilling predicated on integrative approaches that combine gravity and magnetic- with seismic- and geology.

On 29 May 2012, the Petroleum Agency of South Africa (PASA) awarded the Petroleum Oil and Gas Corporation of South Africa (Pty) Ltd. (PetroSA) an Exploration Right for each of Licence Blocks 5/6 (ER #224) and 7 (ER #228) off the south-west coast of South Africa.

On 17 August 2012 PetroSA assigned 80% of its interest and obligations under the Exploration Rights to Anadarko South Africa (Pty) Ltd. and retained a 20% interest. As a result, Anadarko is now the operator of these blocks.

Anadarko is now proposing to undertake a seafloor geochemical sampling programme consisting of seafloor sampling (piston coring), seafloor heat flow measurements and a possible further multi-beam bathymetry survey.

### The Africa Geochemical Database Project

The AGD Project gathered some pace in the last few years in a number of countries (Table 2), thanks to international funding and logistical support from the World Bank, the British Geological Survey, the Norwegian Geological Survey, the China Geological Survey, and others.

A series of Workshops with good African participation was held in Liberia, Namibia, China and other countries by the Global Geochemical Database Task Group and the Chinese Government to promote mapping of the chemistry of the Africa's surface environment in relation to the Global Reference Network (GRN) cells. Previous workshops have been held in China, Iran, Tanzania and other countries.

In December, 2014, the Geological Society of Africa put forward a proposal to UNESCO for pursuance of the first phase of the AGD Project at the global-scale. This will involve low density sampling to document global abundance and distribution of all non-gaseous chemical elements on the surface area of Africa. The work will be co-ordinated by the International Centre for

Global-Scale Geochemistry in Langfang, China, a Category 2 Centre approved and established under the auspices of UNESCO, at the 37th General Conference in November 2013. This Centre was inaugurated in May, 2016.

Table 2. Recent advances in the Africa Geochemical Database Project

| **Country/ Province** | **Cross-sectional Area (km$^2$)** | **Year** | **Sampling Medium/Density** | **Analytical Techniques** |
|---|---|---|---|---|
| Kwa Zulu Natal Province, South Africa | 94,361 km$^2$; (area covered, 3,358 km$^2$) | 2012 - 2015 | Soils: 4 samples per km$^2$ | XRF |
| Madagascar | 587,041 km$^2$ | 2013 - 2014 | Stream sediments: I sample per 100 km$^2$ | -- |
| Nigeria | 923,768 | 2008 - 2012 | Stream sediments: 1 sample per 20 km$^2$ (Minna Cell); 1 sample per 90 km$^2$ (SW Cell) | ICP-MS |
| Sierra Leone | 71,740 km$^2$ | 2012 - 2013 | Stream sediments and panned concentrates: 4,321 samples collected for preparation of 1:10,000 geochemical maps | ICP-MS and ICP-AES |
| Uganda | 241,038 km$^2$ | 2012 | Stream sediments and soils: average of 1 sample per 7.5 km$^2$ (Sampling between 50 and 100 m) | ICP-MS |
| Zimbabwe | 390,757 km$^2$ | 2014 (Reported) | Stream sediments: (Ultra-low density) - 1 sample per 600 to 1,000 km$^2$ | XRF, AFA, OES, and others |

Analytical Geochemistry

New commercial geochemical laboratories, and more branches of existing ones were opened during 2012 - 2016. However, most of their sample preparation and analytical protocols are geared specifically towards mineral exploration, and it is uncertain as to whether all such

laboratories do take part in the *GeoPT* proficiency testing programmes. Their results may therefore be sometimes unsuitable, or have limited usage, for the AGD Project. For this project to progress and succeed, we urgently need a critical mass of well-trained analytical geochemists, while we plan the acquisition of modern analytical instrumentation, and the setting up of a few regional laboratories, taking into account the cost of transporting samples all the way to the laboratory in China.

A large number of international training workshops on Analytical Geochemistry are held annually, but participation of African geochemists is always low, due to a nexus of militating factors, among which are unavailability of travel bursaries and lack of exposure to the active AG fraternity.

**VIII. Geochemistry in Waste Management [Including Mine Wastewaters (AMD)]**

Research on waste management geochemistry in Africa during the period under review has focused (among other relevant sub-themes on the subject), on: (i) methods for safe disposal of hazardous and toxic wastes (e.g., du Toit and Badenstein, 2014); (ii) recognizing the dangers of persistent organic pesticides (POPs), e.g., GEF, 2016), and of course the vexing problem of combating AMD (e.g., Robbins, 2015). Results from these studies are/were presented, discussed, and the way forward charted, in a number of scientific conferences on the subject, such as at the International Mine Water (IMWA) Annual Conferences, e.g., The 2016 IMWA Annual Conference that was held in Leipzig Germany during 11 - 15 July, 2016.

**Conclusion**

Africa holds perhaps the greatest promise for the successful application of AG methods and techniques, given that development of its huge mineral resources endowment potential, and solutions to the myriad of problems created by the continent's unique geoenvironmental circumstances, depend heavily on the efficient application of such procedures.

Apart from the need for fertile and productive agricultural soils to secure food production, Africa is also facing the necessity to create and protect healthy environments in urban and rural areas, to guarantee water and food security, to adapt to, and mitigate the effects of, climate change, and to preserve biological diversity. The role of AP in these challenges can never be over-emphasized.

**References**

Arthur, G.D., Aremu, A.O., Kulkarni, M.G., Okem, A., Stirk, W.A., Davies, T.C. and Van Staden, J., 2015. Can the use of natural biostimulants be a potential means of phytoremediating contaminated soils from goldmines in South Africa? International Journal of Phytoremediation. DOI: 10.1080/15226514.2015.1109602

Buthelezi, S.A. and Davies, T.C., 2015. Carbon monoxide (CO), ozone (O3) and nitrogen dioxide (NO2) exposure from vehicular transportation and other industrial activities in the vicinity of Umlazi Township, South of Durban, KwaZulu-Natal Province, South Africa. Transactions of the Royal Society of South Africa. DOI: 10.1080/0035919X.2015.1046972.

Available at:
http://www.tandfonline.com/eprint/4EFWpidtFKmHMcX6dETW/full#.VZ9qlvmqqko Taylor & Francis

Compton, J.S, Bergh, E.W., 2015. Phosphorite deposits on the Namibian shelf. Marine Geology, http://dx.doi.org/10.1016/j.margeo.2016.04.006 - See more at: http://www.geology.uct.ac.za/prof/john/compton#sthash.bZgS0n24.dpuf.

Davies, T.C., 2015a. Urban geochemistry of Lagos. Proceedings of the 27th International Symposium of the Association of Applied Geochemists, 20 - 24 April, 2015, Tucson, Arizona, USA. Available at: https://www.appliedgeochemists.org/images/stories/IAGS_2015/Abstracts/27th%20IAGS_Davies_Urban%20geochem%20of%20Lagos.pdf.

Davies, T.C., 2015b. Urban geology of African Megacities. Journal of African Earth Sciences, Vol. 110, p. 188 - 226. DOI: 10.1016/j.jafrearsci.2015.06.01, Elsevier.

Darnley AG, Björklung A, Bølviken B et al., 1995. A Global Geochemical Database for Environmental and Resource Management: Recommendations for International Geochemical Mapping. Earth Science Rep 19. Paris: UNESCO Publishing.

DEA (Department of Environmental affairs), 2013. State of Air in South Africa Report. Department of Environmental Affairs, Pretoria,South Africa. 3 p. www.2013_stateofair_summary(3).pdf (Accessed 31.05.16).

du Toit, K. and Bodenstein, J., 2014. Disposal of medical waste: A legal perspective. South African Medical Journal 104 (1). On-line version ISSN 2078-5135

GEF (Global Enironment Facility), 2016. Chemicals and Waste. Global Environment Facility, Washington D.C., U.S.A. www.thegef.org/gef/Chemicals (Accessed 31.05.16).

Kříbek, B., DAVIES, T.C. and De Vivo, B. (Editors), 2014. Impacts of mining and mineral processing on the environment and human health in Africa. “Special Issue”, Journal of Geochemical Exploration, Vol. 144, Part C, p. 387 - 580 (193 pages). Elsevier - http://www.sciencedirect.com/science/journal/03756742/144/part/PC.

Nagaoka, H., Karouji, Y., Arai, T., Ebihara, M. and Hasebe, N., 2013. Geochemistry and mineralogy of a feldspathic lunar meteorite (regolith breccia), Northwest Africa 2200. Polar Science 7 (3 - 4), 241 - 259.

PACN (Pan Africa Chemistry Network), 2012. Increasing Africa’s Agricultural Productivity: A Report by the PACN. http://www.rsc.org/globalassets/04-campaigning-outreach/realising-potential-of-scientists/research-policy/global-challenges/increasing-africa-agricultural-productivity.pdf (Accessed 17.05.16).

Robbins, K., 2015. Acid Mine Drainage and its Governance - Gauteng City-Region. Gauteng City-Region Observatory, Johannesburg, South Africa. 76 p. www.gcro.ac.za/media/reports/amd_occasional_paper_final_web.pd (Accessed 31.05.16).

Schiermeier, Q., 2013. Farmers dig into soil quality: Analytical technique promises to match fertilizers to soil in bid to boost yields in Africa. Nature . doi:10.1038/502607a.

Simonson, B.R., Goderis, S. and Beukes, N.J., 2015. First detection of extraterrestrial material in ca. 2.49 Ga impact spherule layer in Kuruman Iron Formation, South Africa. Geology 43 (3), 251 - 254.

West, A.G., February, E.C. and Bowen, G.J., 2014. Spatial analysis of hydrogen and oxygen stable isotopes ("isoscapes") in groundwater and tap water across South Africa. Journal of Geochemical Exploration 145, 213 - 222.