European Geosciences Union

GIFT – Geosciences Information For Teachers

GIFT Workshop 2016

Mineral Resources – Natural Hazards

Cape Town, South Africa, 27 & 28 August, 2016

Picture credits:
http://www.911metallurgist.com/blog/15-largest-mines-on-earth
Warren Rohner - originally posted to Flickr as Devil's Peak/Table Mountain fire

Welcome!

Dear Teachers,

Welcome to the Cape Town GIFT workshop for Teachers sponsored by the European Geosciences Union, and organized in collaboration with the University of Cape Town, the University of Witwatersrand and the Iziko Museum, in the framework of the 35th International Geological Congress!

The workshop will unite about 50 teachers mostly from South Africa but also from Nigeria and Namibia and is organized over two days: on the first day, we will explore the theme of Mineral Resources, the second day will concentrate on Natural Hazards.

The expansion of the world population from 6 to 9.6 billion in 2050 and the rapid industrialization of highly populated countries combined with an overall higher standard of living are expected to intensify global competition for natural resources and exert additional pressure on the environment, both on land and at sea. It is a fact that reserves of minerals are being exhausted, and worries about access to raw materials, including basic and strategic minerals, are increasing.

The rise in the price of several important metals, for example copper, has prompted some industrialized countries to initiate concerted activities to ensure access to strategic minerals, and Europe has launched several initiatives over the last years in the attempt to solve the issue. Europe, in particular, depends on imports for many of these materials that it needs for construction and for its heavy and high-tech industries. Recycling, resource efficiency and the search for alternative materials are essential, but most specialists agree that this will not suffice and that there is a need to find new primary deposits.

On the other hand, Africa as a continent, and South Africa in particular, are largely provided in mineral resources (not only in diamonds!), as will be discussed in the workshop. Nevertheless, these resources need to be exploited using modern exploration technologies in order to secure the lowest extraction costs and the lowest wasting of materials. Several aspects about the abundance and exploration of the Mineral Resources in Africa will be addressed during the workshop by leading world experts.

In the second day, the workshop will consider some aspects of Natural Hazards.
Natural hazards are potential threats to humans that begin with and are transmitted through the Earth's natural environment, including the lithosphere, the hydrosphere, the atmosphere and the biosphere. Examples of natural hazards include earthquakes, land slides, volcanoes, tsunamis, floods and wildfires.

Both the causes and results of natural hazards provide a dramatic intersection between the physical and social sciences. Many disasters that occur are a complex mix of natural events and human processes. The impact of these disasters on society has increased dramatically over the last couple of decades. All spheres of society are now touched to some extent by natural hazards, whether they involve loss of lives and homes, an increasing strain on country global resources (particularly acute for developing countries). Scientists, both physical and social, have different ways for understanding and studying natural hazards, ranging from mathematical equations, computer models, laboratory experiments and many kinds of ground-based and satellite data. Here, in the one day of the workshop on natural hazards we will have time to describe and discuss only some of the more important natural hazards issues presently facing society, largely taking advantage of the presence in Cape Town of worldwide known scientists attending the 35th International Geological Congress.

As all previous GIFT workshops, the Cape Town workshop will also include some hands-on activities led by science educators, specialists of classroom experiments, which you will be able to show to your kids and have them participate.

We would like to continue to offer teachers the opportunity to attend GIFT and similar workshops, but this depends upon us being able to show our sponsors that teachers have used what they have learnt at the GIFT workshops in their daily teaching, or as inspiration for new ways to teach science in their schools.

Therefore, **we ask you**:

1. To fill out the evaluation form as soon as possible and send it back to us.
2. To make presentations of your experiences at GIFT to a group of your teaching colleagues soon after you return.
3. To send us reports and photographs about how you have used the GIFT information in your classrooms.

We also encourage you to write reports on the GIFT workshop in publications specifically intended for geoscience teachers.

Information on past and future GIFT workshops is available on the EGU homepage (http://www.egu.eu/education/gift/workshops/): At this link it is possible to download brochures (.pdf) of the workshops, presentations given at the GIFT workshops for the last 8 years (.pdf). Since 2009, web-TV presentations were also included, which may be freely used in your classrooms.

We hope you enjoy the GIFT workshop in Cape Town!

The Organizing Committee
of the Cape Town GIFT Workshop

Acknowledgements

The GIFT 2016 Workshop in Cape Town has been organized by the Committee on Education of the European Geosciences Union for the 35th IGC. EGU has supported the major share of the expenses, but the workshop has also benefited from the generous help of:

European Space Agency

Westermann Publishing House

University of Kiel

William S. Goree Award

Esri South Africa

And we thank all the speakers who have contributed to this educational workshop and their institutions!

Organizing Committee

Carlo Laj

European Geosciences Union,
Committee on Education,
École Normale Supérieure,
Paris, France

Friedrich Barnikel

European Geosciences Union, Committee on Education, Educational Coordinator for Geography, City of Munich, Germany

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Honorary Research Associate, Dept. of Geological Sciences, University of Cape Town, Cape Town, South Africa

Gillian Drennan

Associate Professor, School of Geosciences, University of Witwatersrand, Johannesburg, South Africa

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Education Manager, Natural History, Iziko South African Museum, Cape Town, South Africa

Ian McKay

Outreach Manager, Evolutionary Studies Institute, University of Witwatersrand, Johannesburg, South Africa

Andrew Petersen

Education Specialist, Schools Development Unit, University of Cape Town, Cape Town, South Africa

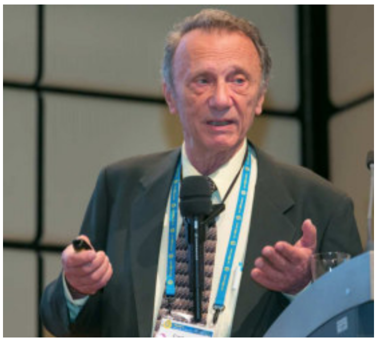
Programme

Saturday August 27, 2016 **Mineral Resources**

08:30 – 08:45	**Welcome & Introduction to the GIFT Workshop** Carlo Laj Chairman, Committee on Education, EGU
08:45 – 09:30	**Mineral deposits – Where did they come from and how did they get there?** Laurence Robb University of Oxford, United Kingdom
09.30 – 10:00	**Earth Learning Idea Hands-On** Chris King Keele University, United Kingdom
10:00 – 10:30	**COFFEE BREAK**
10:30 – 11:15	**Gold, Platinum and Diamonds of South Africa** Judith Kinnaird University of Witwatersrand, South Africa
11:15 – 12:15	**Crystallography made easy – Hands-On** Tanja Reinhardt University of Kwazulu-Natal, South Africa
12:15 – 13:00	**LUNCH**
13:00 – 14:30	**Evolution of Mineral Deposits in South Africa – Hands-On** Ian McKay & Gillian Drennan University of Witwatersrand, South Africa
14:30 – 14:45	**COFFEE BREAK**
14:45 – 15:30	**Resources and Resourcing for Future Generations** Paul Nex University of Witwatersrand, South Africa
15:30 – 17:30 (two groups, swapping after 60')	**Smartphones and Recycling – Hands-On** Heike Ellbrunner & Britta Bookhagen Educational Center for Special Needs, Unterschleissheim, Germany **Iziko Museum Tour** Daksha Naran Iziko South African Museum, Cape Town, South Africa

Sunday August 28, 2016		Natural Hazards
09:00 – 10:00 (two groups, swapping after 30’)	**Teaching Material – New Resources** Wendy Taylor University of Cape Town, South Africa	**Networking** Friedrich Barnikel Committee on Education, EGU
10:00 – 10:45	**Coal in South Africa** Nandi Malumbazo Council for Geoscience, South Africa	
10:45 – 11:00	**COFFEE BREAK**	
11:00 – 11:45	**Seismic Activity in Southern Africa** Mustapha Meghraoui University of Strasbourg, France	
11:45 – 12:30	**Tsunamis in Cape Town** Sharad Master University of Witwatersrand, South Africa	
12:30 – 13:30	**LUNCH**	
13:30 – 14:00	**Tsunami Simulation Hands-On** Chris King Keele University, United Kingdom	
14:00 – 14:45	**Remote sensing and natural hazards – the FUNDISA software and the esa School Atlas** Phila Sibandze South African National Space Agency, South Africa	
14:45 – 15:00	**COFFEE BREAK**	
15:00 – 15:30	**FundaLula – Mapwork with GIS** Tsholofelo Diphoko Esri South Africa	
15:30 – 16:15	**Lighting up the subsurface** John Ludden British Geological Survey, United Kingdom	
16:15 – 16:30	**GOOD BYE!**	

Speakers



Carlo Laj

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Département de Géologie
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Committee on Education
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Education:
Secondary school in Italy and the USA (American Field Service Exchange Student).
University studies at the University of Paris, PhD in Solid State Physics.

Career
I have done all my scientific career as an employee of the French Atomic Energy Commission, first as a researcher in the Physics Department then in the field of geophysics.
In 1985, I was appointed as Deputy Director of the Centre des Faibles Radioactivités and Head of the Department of Earth Sciences. I created and was first director of the Laboratoire de Modélisation du Climatet de l'Environnement, which was later united with the Centre des Faibles Radioactivités to form the present Laboratoire des Sciences du Climat et de l'Environnement (LSCE).After 3 terms as Head of Department (12 years) I stepped down to a researcher position again, until I retired. I have been an "emeritus" researcher since then, and gradually reoriented my activities towards education.

Research Interests:
After my PhD I spent a few years working with critical phenomena (scattering of laser light by critical fluids) then moved into the field of geophysics.
My main interests in this new field has always been linked to the magnetic properties of sediments and igneous rocks (paleomagnetism), used with several objectives: geodynamical reconstructions (particularly in the Eastern Mediterranean and the Andean Cordillera), reconstruction of the history of the Earth's magnetic field (including the morphology of field reversals) and more recently reconstructions of environmental and climatic changes on a global scale.
I have published over 200 articles in international scientific journals and a few general popular articles in different journals.
Supervisor of 12 PhD students, and 8 Masters of Science

Educational activities and Honors:
Founder and Chairman, Education Committee of the European Geosciences Union
Participant to different National and International Education Committees
Union Service Award for creating the Committee on Education of EGU
Excellence in Geophysical Education Award of the American Geophysical Union
Fellow of the American Geophysical Union (AGU).
F. Holweck prize of the French Academy of Science
Holmes Medalist of the European Geosciences Union

THE EDUCATIONAL ACTIVITIES OF THE EUROPEAN GEOSCIENCES UNION

Best practice for the science–teaching interface

C. Laj& the Committee on Education
European Geosciences Union
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Introduction

In 2002 in Nice, France, EGU Executive Secretary Arne Richter announced a collaboration between scientists and schools all over Europe. The aim was to bring state-of-the-art science via high school teachers into tomorrow's classrooms.

Carlo Laj was appointed chair of the EGU Committee on Education (CoE) and, in 2003,the first GIFT workshop took place at the General Assembly, featuring 42 teachers from seven European countries. Since then, more than 1000 teachers have attended these workshops, which are a mixture of presentations by worldwide known scientists, hands on experiences for the classroom and presentations by the teachers themselves to their fellow teachers

The Committee on Education of EGU has progressively developed programs and educational materials mainly aimed at secondary school teachers and pupils along 5main axes:

1) Geosciences Information for Teachers (GIFT) workshops at EGU General Assemblies and more recently at Alexander von Humboldt topical Conferences
2) Educational sessions at EGU General Assemblies (teachers and scientists and science educators)
3) Gift Distinguished Lectures series
4) Teachers at sea
5) GIFT workshops elsewhere from Vienna

These activities are briefly described below.

The GIFT workshops at the EGU General Assemblies in Vienna (Austria)

The program of each workshop is focused on a unique general theme, which changes every year, and which combines scientific presentations on current research in the Earth and Space Sciences, given by prominent scientists attending EGU General Assemblies, with hands-on, inquiry-based activities that can be used by the teachers in their classrooms to explain related scientific principles or topics. Also, teachers are welcomed to present to their colleagues some aspects of their own « out-of-the program » classroom activities.

The main objective of these workshops is to spread first-hand scientific information to science teachers of primary and secondary schools, significantly shortening the time between discovery and textbook, and to provide the teachers with material that can be directly transported into the classroom. In addition, the full immersion of science teachers in a truly scientific context (EGU General assemblies) and the direct contact with world leading geo-scientists are expected to stimulate curiosity towards scientific research that the teachers will transmit to their pupils.

The value of bringing teachers from several nations together includes the potential for networking and collaborations, the sharing of experiences, and an awareness of science education as it is presented outside their own countries. At all previous EGU GIFT workshops teachers mingled with teachers from outside their own country and had lunch together with the scientists, which provided rich dialogue for all those who participated since the dialogue included ideas about learning, presentation of science content, curriculum ideas… We, therefore, believe that, in addition to their scientific content, the GIFT workshops are of high societal value.

The workshop quickly became known amongst teachers all over the European continent and, in the following years, the number of participants doubled. Due to the importance of the valuable hands-on activities, which require an intimate setting, and the limited space at the conference venue, the maximum number of participants had to be limited to 85.

Today a GIFT workshop typically includes :
- Two and a half days of workshop
- 80 participants from 20 countries (selected from 250-300 applicants)
- 8-9 conferences by worldwide known scientists present at the General Assembly
- 1 half-day practical works with specialized educators
- 1 poster session “Science in tomorrow’s classroom” where teachers are encouraged to present their out-of-the-official-program school activities and which is open to non-teachers participants (in 2012 we have had about 50 posters from the teachers attending the GIFT workshop out of a total of about 65)

1 visit to local institutions in Vienna (UNOOSA, IAEA…)

And each GIFT workshops starts with a visit and an ice-breaker reception at the Vienna Museum of Natural History on the Sunday preceding the workshop.

The year 2009 brought further additions to the GIFT concept. For the first time, recordings were made available as web streams and are openly accessible free of charge via the EGU website (http://www.egu.eu/outreach/gift/workshops/).

Also, in 2010, the Committee on Education decided to hold a « local » GIFT workshop associated with EGU Alexander von Humboldt Topical Conferences. These are a series of meetings held outside of Europe, in particular in South America, Africa or Asia, on selected topics of geosciences with a socio-economic impact for regions on these continents, jointly organized with the scientists and their institutes/institutions of these regions.
The first GIFT-AvH took place in Merida (Yucatan), the second in Penang (Malay) the third in Cusco (Peru), the fourth in Istanbul (Turkey) and the fifth in Addis Ababa. Each time we have had a participation of 40-45 « local » teachers.
Noticeably, in the five cases it was the first workshop of the kind organized ever.

Laurence Robb

Visiting Professor
Department of Earth Science
University of Oxford, UK
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Education:
University of the Witwatesrand, Johannesburg, South Africa
1981: PhD
1977: MSc

Affiliations:
Fellow of the Royal Society of South Africa
Fellow of the Geological Society of South Africa
Fellow of the Society of Economic Geologists
Fellow of the Geological Society of London
Chartered Geologist
European Geologist

Career:
1997-2005: Pavitt Professor of Economic Geology, University of the Witwatersrand, Johannesburg.
1999-2000: President, Geological Society of South Africa.
2001-2005: Director, Economic Geology Research Institute, University of the Witwatersrand.
2004-2008: Visiting Senior Research Fellow in Economic Geology, University of Oxford.
2008-present: Visiting Professor in Economic Geology, University of Oxford.

Research Interests:
I am interested in the geological processes that give rise to the concentration of metals in the Earth's crust and the formation of mineral deposits. My research has been conducted in many of the great mineral districts of the African continent, including the Witwatersrand Basin, the Bushveld Complex and the Central African Copperbelt. At present we are studying the tectonic and metallogenic evolution of Myanmar and Malaysia, in SE Asia.
I have written a major text book in economic geology, entitled 'Introduction to Ore Forming Processes' which was published by Wiley-Blackwell in 2005. A second edition of this book is currently in preparation.

MINERAL DEPOSITS – WHERE DO THEY COME FROM AND HOW DID THEY GET THERE?

Laurence Robb
Department of Earth Sciences, University of Oxford, UK

With a global population in 2014 of close to 7 billion people, and this figure set to increase to some 9 billion by 2040, it is apparent that the world's economies are under growing pressure to sustain an increasingly materialistic life-style for its peoples. The unprecedented growth of human population over the past century has resulted in a dramatic increase in demand for, and production of, natural resources - it is therefore evident that understanding the nature, origin and distribution of the world's mineral deposits remains a vital and strategic topic. The discipline of "economic geology," which covers all aspects pertaining to the description and study of mineral resources, is therefore one which traditionally has been, and should remain, a core component of the university earth science curriculum. An understanding of the natural resource cycle is also a subject that school learners should be exposed to as early as possible. There is a multitude of processes that give rise to the concentration of metals in the Earth's crust and the formation of mineral deposits. For the purposes of this presentation I have selected only four processes, very different from one another, that nevertheless provide a useful and informative insight into how metals are concentrated and where mineral deposits are likely to occur. These are:-

Exhalative activity on the sea-floor

Cold sea water is known to circulate through the oceanic crust and in so-doing becomes heated to temperatures as high as 350°C. As it passes through the oceanic crust this fluid dissolves metals such as Cu, Zn, Pb, Ag, Au and Ba and carries them in solution until the point on the ocean floor where the water vents back into the ocean and the metals are precipitated. These vent sites have been described from many different parts of the World's oceanic basins and point to processes that have resulted in very significant concentrations of metals in preserved portions of the oceanic crust. There are many examples of massive sulphide Cu-Zn-Pb deposits around the World (for example, Troodos, Cyprus; Red Dog, Alaska; Broken Hill, Australia) that have formed by processes similar to these.

'Black smokers' and sulphide chimneys at an exhalative vent on the ocean floor

Metals at the 'redox' interface in sediments

Some metals, such as Cu, Co and U, are relatively soluble in oxidized waters but are insoluble in more reduced environments. Others, such as Fe and Mn, exhibit the opposite tendency. Many sedimentary environments comprise basinal fluids that are oxidized and are, therefore, able to dissolve certain metals encountered whilst circulating through the sediment pile. These metals are subsequently precipitated as soon as these fluids interact with more reduced strata, resulting in ore concentrations at the redox interface. One area where this has occurred on a massive scale is in the Central African Copperbelt that straddles a 400km long stretch of the Katanga Basin in northern

Cross-bedded sandstone with concentrations of Cu and Co along foresets representing a redox interface, Mufulira Mine, Zambia

Zambia and the southern Congo. Another example is the 'Kupferscheifer' in eastern Europe. In the Central African Copperbelt most of the stratiform Cu-Co deposits occur stratigraphically beneath a major glacial diamictite unit (the Grand-Conglomerat) that has been correlated with the Sturtian 'Snowball Earth' event. It is suggested that the basin-wide transition from oxidized to reduced conditions that was responsible for metal precipitation and concentration was promoted by global glaciations and anoxia at this particular interval.

Granite formation and mineralization along subducting plate margins

The Earth's surface is made up of rigid plates that move relative to one another. Plate tectonic processes provide the framework for understanding many ore-forming processes. When dense oceanic crust in one plate collides with less-dense continental crust in another (such as along the western edge of present-day South America) the oceanic material is subducted beneath the continental material, resulting in rock deformation and magma formation. The granite magmas that form along subducting plate margins are hosts to major Cu-Mo deposits (known as 'porphyry coppers') that form only 1-3 km below the surface, and also to high-level (or 'epithermal') Au-Ag deposits that typically form in or near to volcanic vents. The water that emanates from these magmas, known as a hydrothermal fluid, carries chlorine and sulphur, that assists in the dissolution of metals such as Cu and Au, the latter themselves derived from the magma.

Magmatic hydrothermal fluid precipitating native sulphur in the vent of a volcano, Kyushu, Japan

Network of intersecting veins cutting a granite porphyry – the veins represent the fossilized pathways of hydrothermal fluid

These hot, metal-charged hydrothermal fluids circulate in and around the granitic intrusions and react with the country rocks through which they pass. The alteration of the country rocks changes the properties of the hydrothermal fluid causing the metals being transported in solution to precipitate out. For this reason granites forming adjacent to subducting plate margins, such as in Chile, are highly prospective around the World for porphyry style Cu-Mo deposits and epithermal Au-Ag mineralization

Basaltic magmatism and fractional crystallization

A very substantial proportion of the World's platinum group element (PGE) and chromium reserves are extracted from mines that occur within the Bushveld Complex in South Africa. The Bushveld Complex is the largest known intrusion of basaltic magma, emplaced some 2050 million years ago and underlying an area of >60 000 km^2. The intrusion forms a large, 7000m thick composite sill that cooled very slowly allowing the sequential crystallization of rock-forming minerals to take place. This process, known as fractional crystallization, allows certain minerals, such as olivine and orthopyroxene, to form and settle at the base of the magma chamber before others such as plagioclase feldspar and clinopyroxene. Fractional crystallization results in the formation of igneous layering within the intrusion, with the composition and mineralogy of the layers evolving progressively in an upward direction. Basal layers, made up of rocks such as peridotite and harzburgite, are overlain by more fractionated layers of gabbro, norite and anorthosite.

The UG1 chromitite layer, Bushveld Complex, South Africa

Perturbations in the normal crystallization sequence, related to events such as the injection of new magma into the existing chamber, periodically occur in the Bushveld Complex. The lower portions of the sequence contain numerous layers of chromite rich rocks, known as chromitite seams, many of which are mined for chromium from layers that extend laterally for hundreds of kilometres. Higher in the sequence magnetite layers also occur and these represent rich resources of Fe, Ti and V that are used in specialized steel industries. Injection of new magma also results in the separation of immiscible sulphide globules that settle to form sulphide-mineral rich layers. In the Bushveld Complex one such layer, the Merensky Reef, hosts the World's largest reserves of PGE, as well as substantial Ni and Cu. The complex crystallization processes that formed the layered intrusion of the Bushveld Complex were extremely efficient at concentrating a wide range of metals into ore deposits that collectively represent one of the most prospective mineral provinces of the World.

To conclude, the formation of mineral deposits occurs in response to the many varied and complex, but otherwise routine, geological processes that accompany the development and evolution of the Earth's crust through time. However, the responsible management and sustainability of the World's finite mineral resource base in the future will need to be carried out by a global population that more fully understands the nature, limits and distribution of its natural resource endowment.

Chris King

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Education:
- BSc Honours in Geology, 2(2); University of Bristol, 1968 - 1971.
- MSc 'Sedimentology', (Distinction); University of Reading, 1976 - 1977.
- Postgraduate Certificate in Education (Geology, Chemistry, Geography); University of Keele, 1977 - 1978.

Career:
- Oct 1971 - July 1976 De Beers Consolidated Mines Ltd., Kimberley, South Africa. Geologist prospecting for diamonds and evaluating diamond prospects in South Africa, Swaziland and Australia.
- Sept 1978 - July 1996 Altrincham Grammar School for Boys, Marlborough Road, Altrincham, Cheshire, WA14 2RS.
School Development Officer and teacher of geology and science.
- Sept 1996 – Aug 2006 Science Education Lecturer/Senior Lecturer: Earth sciences, Keele University
- Sept 2006 – Dec 2015 Professor of Earth Science Education
- Jan 2016 onward Emeritus Professor of Earth Science Education
- Sept 1999 – today Director of the Earth Science Education Unit at Keele University

Research Interests:
All aspects of Earth science education, particularly focussing on misconceptions, professional development and fieldwork.

Publications and services:
- King, C. (2016) Fostering deep understanding through the use of geoscience investigations, models and thought experiments – the Earth Science Education Unit and Earthlearningidea. In Geoscience education: trends and approaches, Ed. Vasconcelos, C. Springer. In press

- King, C. (2013) A review of the Earth science content of Science Textbooks in England and Wales. In Myint Swe Khine (ed) Critical Analysis of Science Textbooks: evaluating instructional effectiveness, 123-160. Dordrecht: Springer. ISBN. 978-007-4167-6.

- King, C. (2013). Using Research to Promote Action in Earth Science: Professional Development for Teachers. In, Vincent Tong (ed) GeoscienceResearch and Education. 311-334. Dordrecht: Springer. ISBN 978-94-007-6942-7

- King, C. (2010) The planet we live on – the beginning of the Earth Sciences. Book published electronically in March 2010 for free download on the Basic Books in Science website at: http://www.learndev.org/ScienceWorkBooks.html#anchor768807 183 pp

- Edwards, D. and King C. (1999) Geoscience - understanding geological processes. London: Hodder and Stoughton. 256pp. ISBN 0 340 68843 2

Awards and Honours:

- 1994 – Honorary Life Member of the Earth Science Teachers' Association (ESTA)
- 2003 – winner of the Geological Society's 'Distinguished Service Award' (… an individual who has made a significant contribution to geoscience and the geoscience community by virtue of their professional, administrative, organisational or promotional activities.)
- 2012 – winner of the Geologists' Association's 'Halstead Medal' (…for work of outstanding merit, deemed to further the objectives of the Association and to promote Geology.)

Earth Learning Idea Hands-On – Mineral resources

Chris King, Keele University, United Kingdom

Earthlearningidea was set up as a result of a failed bid for International Year of Planet Earth (IYPE) funding in 2007. Because of this failure, three Earth Science Education Unit (ESEU) facilitators decided to 'go it alone' on a voluntary basis. They set up the Earthlearningidea website - aimed at publishing a new idea every week during IYPE – particularly for use in developing countries with little or no equipment. By the end of IYPE (2008), 57 activities had been published (5 in the build up to IYPE, 52 in the year).

After IYPE, publication continued at a rate of one activity every two weeks and colleagues in other countries offered to translate the ideas into their own languages. The remit was extended to include expanded activities using 'normal' school lab equipment and more abstract ideas together with 'Early years' activities.

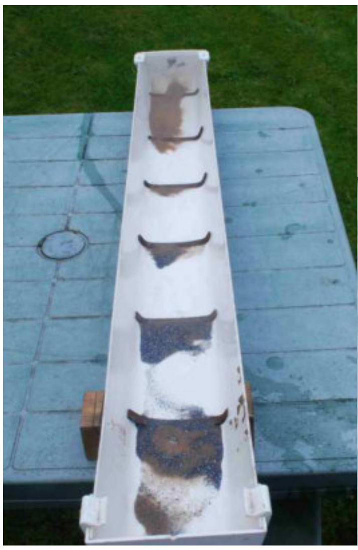
By July 2016:

- 238 activities had been published in English, plus 50 activities in the pipeline
- 700 translations had been made from English, in 11 languages
- There had been more than 2.5 million pdf downloads, averaging more than 50,000 per month
- The blog had been accessed in 199 countries and nearly 1000 towns and cities across the world
- The search engine finds words in any of the languages used

Some of the Earthlearningideas relevant to the GIFT workshop themes will be presented in Cape Town as follows.

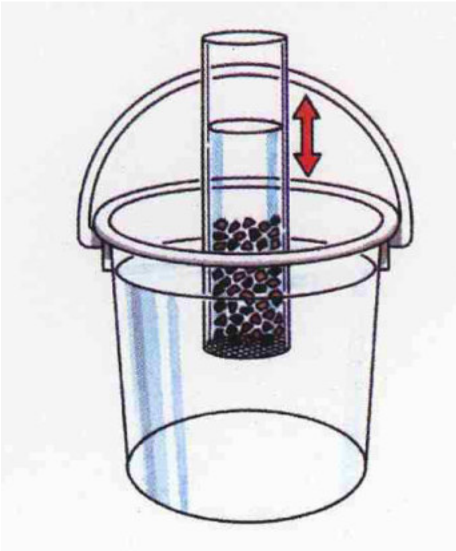
Riches in the river: investigating how valuable ores may become concentrated on river beds

Investigating the importance of differences in density of sand and a valuable ore, to see how the ores may become concentrated by the action of moving water.

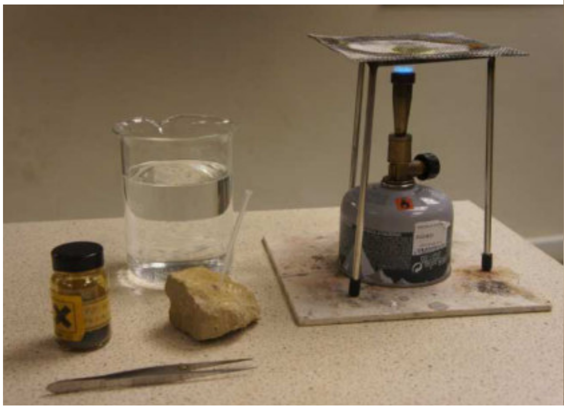


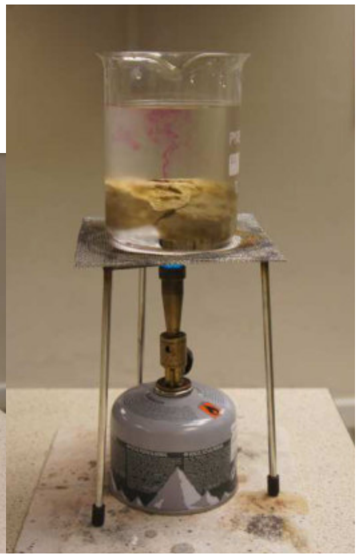
Jigging: using density to separate different materials

A simple practical activity used to separate minerals of different density from each other. It is a small scale version of a method which was used for centuries.



Interactive hydrothermal mineralisation: 'the rock with the hole' hydrothermal mineralisation demo
A demonstration of how hydrothermal fluids flow through rocks, presented in a way to interact with pupils.





A smelter on a stick: smelting iron ore to iron on a gas burner
A simple introduction to the smelting of metal ores by reducing them to the metal with charcoal.

Volcano in the lab: modelling igneous processes in wax and sand
Modelling the rise of "magma" through the "crust", and observing how some of it can erupt onto the surface, representing a lava flow, whilst some sets within the water mass, representing an igneous intrusion.

Tsunami Simulation Hands-On

Chris King, Keele University, United Kingdom

Tsunami: What controls the speed of a tsunami wave?
Investigating the relationship between the depth of water in a tank and the velocity of a water wave generated by lifting and then dropping one end of the tank.

A tsunami through the window - what would you see, what would you feel? Asking pupils to picture for themselves what a tsunami through the window might look like
A ‘thought experiment’ imagining how a tsunami would affect the view through the window.

Judith Kinnaird

Prof
University of the Witwatersrand
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Education:
University of London. University of St. Andrews, Scotland

Career:
Judith Kinnaird is a Professor of Economic Geology in the School of Geosciences and Director of the Economic Geology Research Institute, University of Witwatersrand. She is also co-director of a new National Centre of Excellence (CIMERA) for Minerals and Energy Research Analysis, funded by the NRF/DST of the South Africa government.
She was awarded an Honours BSc degree from the University of London, an MSc and PhD from the University of St. Andrews in Scotland for research on tin-tungsten and columbite-bearing granites in ring complexes in Nigeria. She has taught for the Open University in UK and University College Cork in Ireland where research studies focussed on zinc and copper deposits in Ireland. Prior to taking up a post in South Africa in 1999 she was an independent consultant for six years working on a variety of mineral deposits.
In 1999 she was appointed a research fellow in the School of Geosciences at the University of the Witwatersrand and after two years she joined the Economic Geology Research Institute. At the University of the Witwatersrand she has led a research team involved in research on the Bushveld Complex especially on the Platreef. Currently she is leads a MSc by coursework and research for around 18 postgrads in addition to around 15 postgraduates studying differing types of ore deposits.

Research Interests:
Ore deposits in Africa

Publications:

2016 Huthmann, F., Yudovskaya, M.A. Frei, D., Kinnaird, J.A. Geochronological evidence for an extension of the Northern Lobe of the Bushveld Complex, Limpopo Province, South Africa. Precambrian Research 280; 61–75
2016 Kinnaird, J.A., Milani, L., &Nex, P.A.M. Tin in Africa. Special Issue of Episodes, Mineral Fields of Africa for IGC 2016. 39 (2) 361-380
2016 Kinnaird, J.A., &Nex, P.A.M. Uranium in Africa. Special Issue of Episodes, Mineral Fields of Africa for IGC 2016. 39 (2) 335-359.
2016 Lehmann, J., Saalmann, K., Naydenov, K.V., Milani, L., Belyanin, G.A., Zwingmann, H., Charlesworth, G., and Kinnaird, J.A. Structural and geochronological constraints on the Pan-African tectonic evolution of the northern Damara Belt, Namibia. Tectonics
2016 Yudovskaya, M.A., Naldrett, A.J., Woolfe, J.A.S. Costin, G. and Kinnaird, J.A. Reverse Compositional Zoning in the Uitkomst Chromitites as an Indication of Crystallization in a Magmatic Conduit. Journal of Petrology, 2015, 1–21

Awards and Honours:
She has been a member of the UK Institution of Mining and Metallurgy since the 1970's, is a Chartered Engineer, a fellow of the Geological Society of South Africa, a Fellow of the Society of Economic Geologists, was a Regional Vice President for the Society of Economic Geologists (SEG) a Councillor of the SEG (2010-2013) and President of the SEG (2014). In 2012, she was awarded the Des Pretorius Award of the Geological Society of South Africa for outstanding contributions to the field of Economic Geology and in 2015, the joint awardee of the GSSA Jubilee Medal.

Gold, platinum and diamonds in South Africa

Judith A. Kinnaird

Man has treasured minerals for several millennia, but in the present day environment, there is an ever increasing demand for metals to meet our modern lifestyles. In order to meet our requirements, if we don't fish for it, or grow it, we mine it. South Africa as a country is fortunate to have a large endowment of mineral deposits which we can mine and we are a major world producer of metals like platinum, rhodium, manganese, titanium and chromium.

Although small gold deposits were known by the mid 1850's in various parts of the country, the world-class Witwatersrand Basin that gave rise to the city of Johannesburg was discovered in 1886. Gold was identified in ancient sediments, almost 3 billion years old, which consist of quartz pebbles cemented together with pyrite grains and other minerals. The gold had been washed into an inland sea, known as the Witwatersrand Basin, from mountains to the north and west and deposited in coarse-grained sedimentary layers known as conglomerates. These form part of a thick package of sedimentary rocks that in places is more than 7 km thick. The basin is oval in shape, 350 km long and 150 km across. Over a period of almost 1 billion years, gold was re-mobilised and re-concentrated by hot fluids circulating within the basin. Although since the early 2000's South Africa has fallen from being the No. 1 world producer, to 6^{th} most important, more gold resources remain in the ground in the Witwatersrand Basin than in any other country. The challenge is to mine this gold from depths in excess of 4 km.

The first mention of platinum in South Africa was in a Pretoria newspaper in 1885 and it was subsequently identified in a stamp battery on a gold mine in 1890. However, it was the discovery of the Merensky Reef in August 1924 that led to South Africa becoming of world importance for platinum. Volcanic activity led to the development of the giant Bushveld Complex, which covers an area of at least 90 000 km^2. Molten magma accumulated at shallow depth and over a period of around 1 million years built up to a thickness of 9 km. The complex is saucer-shaped with layers dipping inwards from the edge towards the centre of the complex. Chromite-rich layers occur in three groups, a lower , middle and upper group, and while the lower and middle groups are mined for their chrome content – which goes to make stainless steel, one of the upper group is mined for its high platinum content of ~6 grams per ton. This layer, called the UG2 is now a more important producer than the Merensky Reef as it has only been mined since 1989, whereas the Merensky Reef has been mined since the 1020's. The predominant use of platinum and other platinum group elements is for automobile catalytic convertors.

Diamonds were first discovered in river gravels along the Vaal and Orange Rivers in the northern Cape. Their discovery marked a milestone in South Africa's economic development. It attracted an influx of experienced prospectors and miners and paved the way for the later discovery and development of the goldfield of the Witwatersrand Basin. Although the first diamonds came from river gravels, the economically important occurrences are in a rock called kimberlite. These formed when magmas brought molten material from depths of at least 120 km, carrying in the magma diamonds and fragments of the rocks that the magma passed through. In some places like at Orapa and Jwaneng in Botswana, the crater ashes of the volcano are preserved. In other places such as Kimberley, much of the carrot-shaped pipe has been eroded away releasing diamonds into surrounding streams. Of around 850 known kimberlites in southern Africa, only 50 bear diamonds, and not all of these are economic to mine.The oldest kimberlite pipes intruded at 1800 Ma in theKuruman area but the period from 110 -100 million years ago was the peak of kimberlite emplacement. Although diamond mining began in 1871, surprisingly large diamonds are still being found in various parts of southern Africa. Currently, around 4% of the world's diamonds are mined from South Africa making us around the 6^{th} biggest world producer.

Tanja Reinhardt

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Education:
1992 Diploma in Mineralogy, Ruhr-University Bochum
1997 PhD in Mineralogy, Ruhr University Bochum, Bochum

Career:
1992-1995 Research Assistant, Ruhr-University Bochum, Bochum
1998-2000 Junior Support Engineer, I.T. Manpower and CompuNet, Wiesbaden
2000-2004 Lecturer (School of Geological and Computer Sciences), University of Natal, Durban
2005-2007 Curator, Geology Education Museum, University of Natal, Durban
Since 2008 Science Centre Coordinator, Science and Technology Education Centre, University of KwaZulu-Natal, Durban

Research Interests:
Geoscience Education and education in an informal learning environment

Publications and Services:
2009 Reinhardt T. and Richards N., Tsunami.set of 2 posters funded through the South African Agency for Science and Technology Advancement (SAASTA). These posters have been distributed to South African schools during National Science Week.

Awards and Honours:
Awarded the Sustainability in Science Museums Fellowship in 2016, Walton Sustainability Solutions Initiatives at Arizona StateUniversity.

Best workshop presenter 2013, SciFest Africa, Grahamstown

Crystallography made easy – Hands-On

Tanja Reinhardt, University of KwaZulu-Natal, Science and Technology Education Centre

Introduction

Every year Science Centres around South Africa are faced with the challenge to design activities revolving around “International year” themes and Science Centres have a mandate to promote the specific sciences on which an “International Year” focuses to learners.
In 2014 Science Centres were challenged to carry out a crystallography workshop to promote the International Year of Crystallography. The Science and Technology Education Centre (STEC) at the University of KwaZulu-Natal, which includes the Geology Education Museum developed a crystallography workshop which was made available to other Science Centres in the country.The targeted age group ranges from grade 9-12, but we also presented the workshop to grade 7 learners and younger.

The workshop concept

Research on the International Year of Crystallography website revealed that the education material offered was not always suitable for the age group we wanted to target. The website offered internet courses on structure determination or teaching guide for X-Ray and neutron diffraction, which were aimed at University students but not learners. Other ideas offered included crystal growing activities which were too time-consuming. It usually takes at least one day to grow for example borax or copper sulphate crystals. We therefore decided to design our own workshop around the theme. As crystallography includes many different aspects such as symmetry and crystal structures we needed to focus on particular aspects.

We wanted the learners to appreciatethat minerals consist of atoms that are connected through bonds. They should understand that minerals have a three-dimensional crystal structure and that the crystal structure and the chemical composition determines what type of mineral we get. We also wanted them to be aware that scientists usually determine crystal structures using X-rays.

Mineralogy and in this case the understanding of crystal structures of minerals covers abstract concepts of chemistry. Learners are requested to understand atomic or molecular structures in three-dimensions, concepts that even University students have difficulties to grasp.

It has long been recognized that physical three-dimensional models are useful tools to help learners visualize and understand abstract concepts (Ingham& Gilbert, 1991, Barke 1993).We therefor decided to let them rebuild the crystal structure model of an “unknown” crystal and compare the model to a variety of other structures in order to determine what the unknown crystal is. Ball-and-stick models are routinely used to visualise crystal structures in teaching at high school or university level, and ball-and-stick kits are available to build these models in groups. Unfortunately,such models come at a price. As one of our requirements was low cost we decided to use coloured sweets and toothpicks to build the models.

Structure of the workshop

The workshop consists of an introductory talk and a hands on activity and follows the Confucius quote: “I hear and I forget, I see and I remember, I do and I understand”.

“I hear and I forget” - the learners get a brief introduction about what a mineral is, what a crystal structureis, as well as information about crystallography, atoms and bonds and X-ray diffraction. Teachers can decide on how much they want to go into details about the various bond types and the structures of atoms.

“I see and I remember” - the learners will see short video clips about the International Year of Crystallography X-ray diffraction and a about ionic and covalent bonds in the presentation. During the talk we show the learners a single grain of salt and challenge them to estimate how many atoms fit into a salt grain. This provides an opportunity to “show” how small in fact atoms are. We also do a short demonstration on diffraction using a laser pointer with diffraction grating.

“I do and I understand” – the learner do the hands on activity and build a crystal structure (galena or salt) out of sweets and toothpicks. We usually work in groups of 3, so that everybody gets to build a layer.

Groups of 3 build the individual layers of the structure…

…and assemble the structure

Learners with the finished model

Learners compare their 3D structures to the printed 2D crystal structures

Once the model is finished they compare it to the crystal structure pictures of sphalerite, diamond, graphite, salt (halite), galena, olivine, fluorite and pyrite and try to identify their structure. To make it more relevant we put samples of the above minerals next to their crystal structures.

Gillian Drennan

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Education:
Gillian Graduated with a BSc (**Majors:** Geology, Geography, Earth Sciences) in 1985 and with her BSc (HONS) in 1986. Here research involved a detailed study of the Natal Group Sandstones, South Africa; she graduated with her MSc (with Distinction) in 1088. Herthesis involved researching the nature of the Archaean basement in the hinterland to the Welkom Goldfield. Gillian graduated with her PhD (Geology/Geochemistry) in May 1998. Her thesis was entitled 'Fluid inclusion microthermometry of the Witwatersrand Basin'.

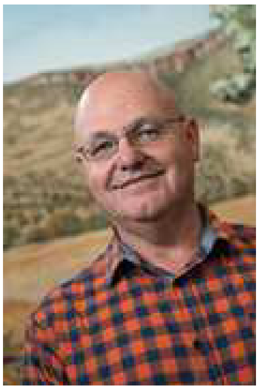
Career:
Gillian has been lecturing Geology in the School of Geosciences, University of the Witwatersrand, since 1993, first in a bridging programme, the College of Science, and then in the mainstream classes. She has served as the course coordinator of the first-year programme since 2006. She also supervises postgraduate research. Gillian was elected a Fellow of the Geological Society of South Africa in 2006 and was promoted to Associate Professor in the School of Geosciences in 2008. She served as the Assistant Dean (Undergraduate Affairs) in the Faculty of Science (2008 – 2015) and is also the Deputy Head for the School of Geosciences at WITS.

Research interests:
Gillian's main focus of research is the association between hydrocarbons and gold mineralization, especially within the Archaean Witwatersrand Basin. She also oversees research into coal, coal properties and characteristics, as well as coal benificiation within the Geosciences. She also researches Geoscience Education matters such as 3-D visualization problems and threshold concepts such as deep time. Gillian has supervised many Geology Honours Research Projects, 9 MSc Research Projects and 2 PhD Research programmes.

Publications and Services:
Gillian has published a number of scientific papers and extended abstracts. Highlighted publications include:
Drennan, G.R. and Robb, L.J., (2006). The nature of hydrocarbons and related fluids in the Witwatersrand Basin, South Africa; their role in metal redistribution. Geological Society of America Special Paper 405, Processes on the Early Earth (edited by W. U. Reimold and R. L. Gibson), Ch 18, 353 – 385.
McKechnie, C., Grab, S., and Drennan, G.R. (2007). Documenting lichen-induced mechanical weathering of quartzitic sandstone at Kaapsehoop, Mpumalanga. South African Journal of Science, 103, March/April 2007, 117 - 120.
Drennan, G.R. and Evans, M.Y. (2011). Introductory geological mapwork – an active learning classroom. Journal of Geoscience Education, 59, 56 – 62.

Gillian is a member of the Geological Society of South Africa (GSSA), and the International Geoscience Education Organization (IGEO). She serves as Chairperson for the Museum Consultative Committee as well as the Geological Museum Association, Museum Africa, Johannesburg.

Awards and Honours:
In 1991 she was co-awarded the Jubilee Medal for a paper entitled "The distribution of radio-elements in Archaean granites of the Kaapvaal Craton with implications for the source of uranium in the Witwatersrand Basin" by the Geological Society of South Africa. She is passionate about teaching Geosciences and has received the following awards in recognition of her contribution to Geoscience Education: Convocation Distinguished Teacher's Award (2000), Vice-Chancellor's Individual Teaching Award (2001), the Geological Society of South Africa Honours Award (2002), Convocation Distinguished Team Teacher's Award (2007), and the Vice-Chancellor's Team Teaching Award (2007).



Ian McKay

Dr
Evolutionary Studies Institute, University of the Witwatersrand
ian.mckay@wits.ac.za

Education:

1980-1983 BSc
BSc (Hons)1984
PhD 1985-1990
HdipEd (teaching diploma) 1995
Most of an Mba 2005-2008

Career:

1991-1994, Veterinary Entomologist, Onderstepoort Veterinary Institute
1996-2001, Consultant and producer of curriculum support materials, Environmental Education, Science and Biology, RADMASTE Centre, (NGO: Research and Development in Maths and Technology Education)
2000-2003, Consutant and leader of a Sciences Curriculum Support Document team, Gauteng Department of Education
2001-2014, Managed Palaeontology Outreach for the Bernhard Price Institute of Palaeontology
2003-2005, Education Consultant Greenhouse Management Services
2005-2014, Education Consultant, own company ITM Development Management Services
2014-2016, Head of Section: Education and Outreach, Evolutionary Studies Institute, University of the Witwatersrand and Education Officer for the NRF/DST Palaeosciences Centre of Excellence

Research

- Palaeo-entomology
- Earth System Science and Environmental Education
- Teaching of Evolution
- Learning in free choice and informal settings

Publications and Research Interests

1. MCKAY I. J. 2013. Human Evolution. In. de Fontaine J., Dugard J., Freedman R., Marchant L., McKay I., Simenson R., Webb J. Life Sciences, Solutions for All, Grade 12. Macmillan South Africa.
2. MCKAY I.J., WEBB J.,MARCHANT L., FREEDMAN R., SIMENSON R. ., DE FONTAINE J., CD VAN DER MERWE.2012. Grade 11. Life Sciences, Solutions for All. Biodiversity of Microorganisms. Diversity of Microorganisms. History of Life on Earth. MacMillan, South Africa.
3. MCKAY I.J., WEBB J.,MARCHANT L., FREEDMAN R., SIMENSON R. ., DE FONTAINE J., CD VAN DER MERWE.2012. Grade 11. Life Sciences, Solutions for All. Biodiversity of Animals History of Life on Earth. MacMillan, South Africa.
4. MCKAY I.J., WEBB J.,MARCHANT L., FREEDMAN R., SIMENSON R. ., DE FONTAINE J., CD VAN DER MERWE. 2012. Grade 11. Life Sciences, Solutions for All. Loss of Biodiversity. History of Life on Earth. MacMillan, South Africa.

5. DEFONTEIN J.L., FREEDMAN, R, MCKAY I.J, R. WEBB J. 2011. Solutions for All Life: Sciences Grade 10, Teachers and Learners Book, MacMillan South Africa,
6. BOWIE, M., DUGARD J., FREEDMAN, R, MCKAY I.J, PILLAY, R. WEBB J. 2009.Life Sciences For All Grade 11, Teachers and Learners Book, MacMillan South Africa Johannesburg
7. DE FONTEIN J.L, MCKAY I.J, SELEPE, C, WEBB J. 2009. Science Alive Grade 9, Teachers and Learners Book, Nolwazi Publishers: Johannesburg
8. DE FONTEIN J.L, MCKAY I.J, MAHOOANA, P; SELEPE, C, WEBB J. 2006.Life Sciences For All Grade 11, Teachers and Learners Book, MacMillan South Africa Johannesburg
9. DE FONTEIN J.L, MCKAY I.J, SELEPE, C, WEBB J. 2006. Science Alive Grade 8, Teachers and Learners Book, Nolwazi Publishers: Johannesburg
10. DE FONTEIN J.L, MCKAY I.J, WEBB J. 2005. Science Alive Grade 7, Teachers and Learners Book, Nolwazi Publishers: Johannesburg

Evolution of Mineral Deposits in South Africa Hands-On

Ian McKay and Gillian Drennan

University of the Witwatersrand, Johannesburg

Teachers and students find it difficult to understand the concept of deep time. They also find it very difficult to memorise sequences of geological events, how many millions of years ago they occurred, the reason for their formation and the geological period in which they occurred. The situation is analogous to having to memorise long lists of dry dates and events in a history class. However, ifthe learners are given a series of pictures illustrating different events at different times they can often intuitively place them in correct order, or semi correct order, and will find it much easier to memorise, understand and place the events in absolute time.

In this exercise teachers are given a series of diagrams representing the evolution of the Earth's crust, South African mineral deposits, and life over the history of the Earth. They are asked to place the events in chronological order and as they attempt the exercise are given simple rules to help them sequence the cards correctly. At the end they are given the correct sequence of events, and a summary of the rules. Because they have been actively grappling with the problem of trying to understand the evolution of mineral deposits in South Africa- they will have a much better understanding of what the deposits are, the factors governing their formation and evolution through time. This workshop will deal, amongst others, with the Witwatersrand Goldfields, Bushveld Complex, the Ecca Coalfields and Diamond bearing Kimberlite Pipes.

Britta Bookhagen

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Education:

- 2006 Diploma in Geology at Freie Universität Berlin, Germany
- 2003-2006 Teaching studies in mathematics and physics, Freie Universität Berlin, Germany
- 2002 pre-Diploma in Geosciences at Universität Potsdam, Germany

Work Experience

- Since 2015: Federal Institute for Geosciences and Natural Resources, Berlin, Germany
- 2012-2015: Research Associate, IASS Potsdam, Germany
- 2010-2012 Educator/Project Leader, Natural History Museum, Vienna and Austrian Academy of Science, Austria
- 2008-2010 Educator, Boston University School of Medicine, Boston, USA
- 2007-2010 Outreach Manager, Massachusetts Institute of Technology, Cambridge, USA
- 2005-2007 Research and Teaching Assistant, GFZ Potsdam, Germany

Publications

Nordmann, J., Welfens, M.J., Fischer, D., Nemnich, C., **Bookhagen**, B., Bienge, K., Niebert, K. (2014): *Die Rohstoff-Expedition, Entdecke, was in (deinem) Handy steckt*. Springer Spectrum, Didaktik der Naturwissenschaften, Berlin.

Bookhagen B, Buchwaldt R, McLean N, Rioux M and Bowring S (2014): *Earthtime: Teaching Geochronology to High School Students.***.** In: Tong, V. C. H. (ed.), Geoscience Research and Education, Springer, Dordrecht

Welfens, **Bookhagen**, Nordmann, Reimann (2013): *Rückgabe und Nutzung gebrauchter Handys*. SÖF Mitteilungen des BMBF GAIA 22/2 (2013): 128–131

Bookhagen, B. (2012) *Rohstoffkoffer: Was steckt im Handy?* LehrerInnenbroschüre. 76 S. Verlag Naturhistorisches Museum Wien, ISBN 978-3-902421-73-9

Bookhagen, B., Buchwaldt R, McLean N, Rioux M and Bowring S (2010): *Lesson plan and activities for teaching U-Pb radiometric dating*, EARTHTIME http://www.earth-time.org/Lesson_Plan.pdf

Heike Ellbrunner

Teacher
Sonderpädagogisches Förderzentrum Unterschleißheim, Germany
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Education:

Since 1996 teacher for special education (tenure), teacher trainer

Specialities:

Speech development training; learning support for children with special needs; spatial orientation; sustainability in the curriculum

Publications:

ELLBRUNNER, H., F. BARNIKEL & M. VETTER (2014): “Geocaching“ as a method to improve not only spatial but also social skills – Results from a school project.-In: Vogler, R., A. Car, J. Strobl & G. Griesebner [Hrsg.]: GI_Forum 2014 – Geospatial Innovation for Society (Berlin), pp. 348-351.

BARNIKEL, F., H. ELLBRUNNER & M. VETTER (2014): Teaching Spatial Competence Today – From Analogue Maps to Geocaching, Kartographische Nachrichten, 5/64, pp. 257-262.

Mineral Resources in Mobile Phones - a Hands-On Tool for Schools

Britta Bookhagen & Heike Ellbrunner

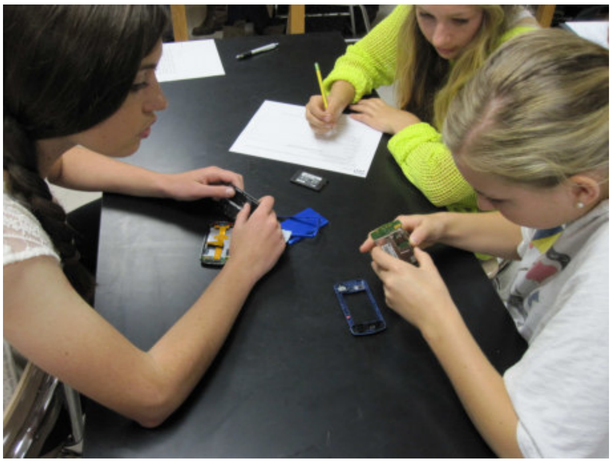
Find out what‘s in your cell phone!

Workshop Description:
In this hands-on workshop for teachers, mobile phones are used as an example for mineral resources in our daily lives. The interdisciplinary teaching material was developed for students ages 14 and up to raise awareness for our resource-rich lifestyle. More than 90% of students own a mobile phone. This workshop will demonstrate how to engage your students in this up-to-date topic. The teaching box contains eleven raw materials (minerals and ores), which are being used as basic materials for the mobile phone production. A mobile phone will be disassembled and linked to the raw materials from the box. Example exercises from the workshop can be directly transferred to classrooms. Topics covered in this workshop include exercises and discussions about the ecological and social impacts of mining of the raw materials and the distribution of "critical" materials and problems during manufacturing (e.g., working conditions). Also, the energy consumption during the life time of mobile phones is evaluated and the necessity of recycling to preserve our resources („urban mining") will bediscussed. Valuable background material about these issues will be provided as well as information on how to make usage of a mobile phone more sustainable.

Facts:
Interdisciplinary subject for teachers in geography/ earthsciences, chemistry, physics, biology, sociology
For Students aged 14+

Basic idea:
- Mobile phones contain up to 45 elements, 30 of which are raw and expensive metals such as gold, silver, palladium. Mining of these ores often is associated with social and ecological problems.
- Teaching-box contains eleven minerals and ores (raw materials), which are being used as basic materials for cell phone production; the providededucational game is used to determine the minerals and sort them to the components of a mobile phone that they are being processed to.
- Fun and experimental, awareness rising without a pointing finger
- makes students also aware about resources in other devices and that everything we use is linked to Earth (where the resources come from)

Examples for interdisciplinary teaching linkages:
- Biology: impact of mining on environment, animals and humans
- Chemistry: Chemistry of the elements, metals, alloys, technical chemistry and applications
- Physics: conductors, technical use, capacitors
- Geography: physical and industrial geography (formation of lagerstätten, distribution of "critical" materials, prospecting and mining, raw materials/commodities, value chains, geopolitical issues)
- social and political aspects: social-political conflicts arising through mining (child labour, working conditions, security), for example the conflict mineral tantalite („Coltan") prolonged civil war in DR Kongo

Disassembled mobile phone and the quiz for determining the raw materials contained in it

Wendy Taylor
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School of Earth and Space Exploration
Arizona State University
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Education:
1989 BSc in Geology, State University of New York, Fredonia, USA
1994 MSc in Geosciences, University of Rochester, USA
1997 PhD inGeosciences, University of Rochester, USA

Career:
University of Cape Town, Rondebosch, South Africa:
2012-present Honorary Research Associate
School of Earth and Space Exploration, Arizona State University, Arizona, USA:
2012-present Faculty Research Associate
2010-2012 Education & Outreach Coordinator, EarthScope National Office
2009-2012 Assistant Director, Robert S. Dietz Museum of Geology
2008-2011 Education and Public Outreach Lead, ASU-NASA Astrobiology Program
2007-2011 Education and Public Outreach Lead, NASA Lunar Reconnaissance Orbiter Camera
2007-2011 Education and Public Outreach Coordinator, Center for Meteorite Studies
2006-2011 Assistant Director and Instructional Specialist Coordinator, ASU-NASA Mars Education Program
The Field Museum, Chicago, Illinois, USA
2005-2006 Curriculum Specialist and Program Developer
2000-2002 Collections Manager, Fossil Invertebrates
University of Chicago, Department of Organismal Biology and Anatomy, Chicago, Illinois, USA
2002-2005 Project and Collections Manager, (for Dr. Paul Sereno)
Paleontological Research Institution, Ithaca, New York, USA
1995-1999 Collections Manager

Research interests:
Evolution of complex animals (Ediacaran-Cambrian boundary), invertebrate paleontology and taphonomy, geoscience eLearning and instructional design

Publications and Services:

2012-present Volunteer Educator, Education and Public Programmes Department, Iziko South African Museum, South Africa; Content Specialist, University of Cape Town, Schools Development Unit, South Africa; Instructor (paleontology modules), Department of Geological Sciences, University of Cape Town, South Africa

Reid, M., Bordy, E., and Taylor, W.L., 2015, Taphonomy and sedimentology of an echinoderm obrution bed in the Lower Devonian Voorstehoek Formation (Bokkeveld Group, Cape Supergroup) of South Africa. Journal of South African Earth Sciences 110, 135-149.

Taylor, W. L., 2006, Educator Guide to Evolving Planet, The Field Museum, 100 p.

Högström, A. and Taylor, W. L., 2001, The machaeridianLepidocoleussarleiClarke, 1896, from the Rochester Shale (Silurian) of New York State. Palaeontology44, 113-130.

Högström, A. and Taylor, W. L., 2001, Lepidocoleus cf. ulrichi(Machaeridia) from the Trenton Group (Ordovician) of Ontario (Canada). PaläontologischeZeitschrift75, 13-16.

Hughes, N.C., Collier, F.J., Kluessendorf, J., Lipps, J.H., Taylor, W.L., and White, R.D., 2000, Fossil Invertebrate and microfossil collections: Kinds, uses, users. In White, R.D. and Allmon, W.D., eds.,Guidelines for the Management and Curation of Invertebrate Fossil Collections. The Paleontological Society Special Publications 10, 25–35.

Taylor, W. L. and Brett, C.E., 1999, Middle Silurian Rochester Shale of Western New York, USA, and Southern Ontario, Canada. In Hess, H. and Simms, M., eds.,Fossil Crinoids. Cambridge

Awards and Honours:

2016: DST-NRF Centre of Excellence in Palaeosicences; 1) Exploring an Ophiuroid-Stylophoran Assemblage from the Devonian Voorstehoek Formation, Bokkeveld Group, Western Cape: Taphonomy, Palaeoecology&Taxonomy, 2) Resolving the Ediacaran-Cambrian boundary within the Vanrhynsdorp Group, South Africa, and 3) Science Alive! Fossilization Module: Using Adaptive eLearning strategies to teach core concepts in the palaeosciences. 60,000 ZAR

2015: DST-NRF Centre of Excellence in Palaeosicences; 1) Taphonomy and Palaeoecology of Ophiuroid-Stylophoran Assemblages from the Devonian Voorstehoek Formation (Ceres Subgroup, Bokkeveld Group, Cape Supergroup), Western Cape and 2) Palaeontology as a tool in developing a sequence stratigraphic framework for the Neoproterozic to Cambrian Vanrhynsdorp Group in NW South Africa. 115,000 ZAR

2014: Norwegian Research Council; The Digermul Peninsula, Norway – a window into the early diversification of animal life, Participating Scientist, University of Cape Town, South Africa. 1,600,000 NOK

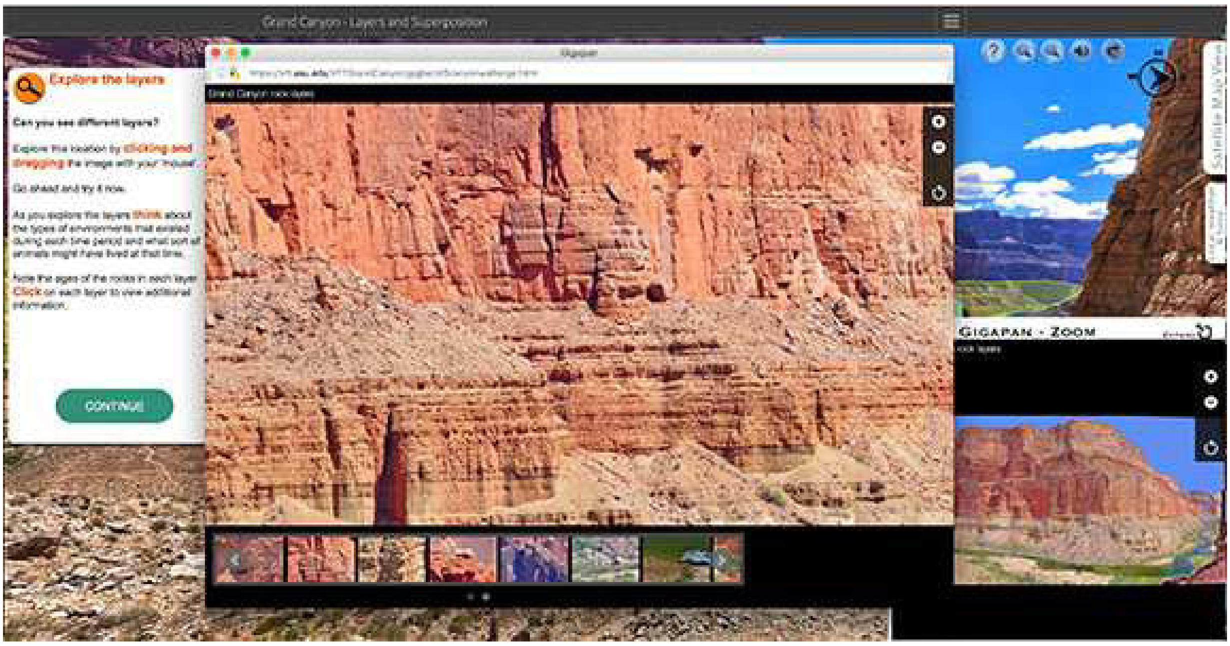
Using Immersive Virtual Field Trips (iVFTs) to Teach Geoscience
Wendy Taylor

The use of virtual environments in geoscience education has been until recently limited by the difficulty of guiding a learner's actions within those environments. New advances in education software technology now allow educators to create interactive learning experiences that respond and adapt intelligently to learner input within the virtual environment. This innovative technology provides a far greater capacity for delivering authentic inquiry-driven educational experiences in unique settings from around the world.

Our immersive virtual field trips (iVFT) bring students virtually to geologically significant but inaccessible environments, where they learn through authentic practices of scientific inquiry. Developed at Arizona State University (USA), with funding from NASA, the Gates Foundation and the Howard Hughes Medical Institute, a new online library of iVFTs is now available to help educators teach core geoscience concepts (http://vft.asu.edu, image below) using the Web.

In one recent example, students learn about fossils by exploring the fossil beds in Nilpena, South Australia. Students interactively engage in 360° recreations of the environment, uncover the nature of the historical ecosystem by identifying fossils with an onlinekey, explore actual fossil beds in high resolution imagery, and reconstruct what an ecosystem might have looked like millions of years ago in an interactive simulation. In another iVFT, students can learn about rock layers and superposition by visiting the Grand Canyon in Arizona, USA (see next page).

With the new capacity to connect actions within the iVFT to an intelligent tutoring system (online platform called Smart Sparrow), these learning experiences can be tracked, guided, and tailored individually to the immediate actions of the



student. This new capacity also has great potential for educators and learning designers to take a data-driven approach to lesson improvement and for education researchers to study learning in virtual environments.

Such iVFTs are currently in use in several introductory classes offered online at Arizona State University in anthropology, introductory biology, and astrobiology, reaching thousands of students to date. Drawing from these experiences, we are designing a curriculum for historical geology that will be built around iVFT-based exploration of Earth history. Additionally, a lesson library will eventually be available through the developing **Inspark Science Network**, a new teaching network built for educators around the globe and fueled through a bold partnership among world-leading universities, community colleges, an education technology company, scientists, and education experts. Inspark is led by a partnership between Smart Sparrow and Arizona State University, with founding partners including Achieving The Dream, E*mersion, and the University of Texas at Arlington.

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Education and Career:

Since 2010: Educational Coordinator for Geography, City of Munich, Germany
2003: PhD in Natural Hazards Research, University of Goettingen
2000 – 2008: Lecturer for Geography, University of Munich
Since 2000: Full time teacher (tenure) for Geography, History and English in Munich

Research interests:

Spatial Orientation, Sustainability Studies, Bilingual Studies, Natural Hazards Research

Publications:

BARNIKEL, F. & R. PLÖTZ (2015): The Acquisition of Spatial Competence – Fast and Easy Multidisciplinary Learning with an Online GIS, European Journal of Geography, 2/6, pp. 6-14.
BARNIKEL, F. & M. VETTER (eds., 2015): Diercke Ressource Wasser – Methoden und Aufgaben (Braunschweig).
BARNIKEL, F., H. ELLBRUNNER & M. VETTER (2014): Teaching Spatial Competence Today – From Analogue Maps to Geocaching, Kartographische Nachrichten, 5/64, pp. 257-262.
BARNIKEL, F. & M. VETTER (2012): Earthquakes in history – Ways to find out about the seismic past of a region.-In: D'Amico, S. [Hrsg.]: Earthquake Research and Analysis – Seimsology, Seismotectonic and Earthquake Geology (Rijeka), pp. 1-20.
BARNIKEL, F., & E. GEISS (2008): The BASE-Project – An open-source catalogue for earthquakes in Bavaria, Germany, Natural Hazards and Earth System Sciences 8/6, pp. 1395-1401.
BARNIKEL, F. & A. v. POSCHINGER (2007): How historical data can improve current geo-risk assessment, Zeitschrift für Geomorphologie N.F. 51/1, pp. 31-43.
BARNIKEL, F. (2004): The value of historical documents for hazard zone mapping, Natural Hazards and Earth System Sciences 4/4, pp. 599-613.

Awards:

Best lecturer award in Geography, University of Munich (2008)

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Education:

- PhD (Chem. Eng.) in Coal Chemistry, School of Chemical and Metallurgical Engineering, 2008 - 2010, University of Witwatersrand.
- MSc in Synthesis Organic Chemistry, 2007-2008, University of the Western Cape.
- BSc (Hons) in Chemistry, 2006, University of the Western Cape.
- BSc in Natural Sciences, 2005, University of the Western Cape.

Career:

- Shale gas research – Project Management, Gas analysis studies, Hydrogeology and Environmental studies and geological mapping.
- Accredited Coal Petrographer – Raw coal and Coal blend.
- Coal to energy research – Coal bed Methane, Carbon Capture and Storage, Coal characterization, Coal Petrography, Coal combustion and gasification.
- Potential of Carbon Capture Technologies in South African (Oxy-coal combustion) – Post Doctoral Project at CSIR.
- Climate change issues concerning the utilization of coal for energy production – Post Doctoral project at CSIR.

Research interests:

- Shale gas
- Coal chemistry

Publications and Services:

- **M. Ndhlalose, N. Malumbazo, N. J. Wagner.** Coal quality and uranium distribution in Springbok Flats coalfield samples. The Journal of the Southern African Institute of Mining and Metallurgy, Volume 115, December 2015, page 1167 – 1174.
- **N. Malumbazo**, N. J. Wagner, J. R. Bunt. The impact of particle size and maceral segregation on char formation in a packed bed combustion unit. Fuel, Vol 111, pg 350-356.
- **N. Malumbazo**, N. J. Wagner, J. R. Bunt, The petrographic determination of reactivity differences of two South African inertinite-rich lump coals. Journal of Analytical and Applied Pyrolysis, Vol 93, pg 139-146.
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TYPE, DISTRIBUTION AND USE OF COAL IN SOUTH AFRICA

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Coal is a heterogeneous material which is formed from plant remains that have been compacted, hardened, chemically transformed and metamorphosed by heat and pressure over geological time from peat forming environments. The peat environments may be swamps and/or marsh. Peat normally has a moisture content of 90%, loss of water is crucial in the conversion of peat to lignite which is the lowest rank of coal. Lignite is then converted by dehydration and methanogenisis to sub-bituminous coal. A further dehydration reaction occurs progressively removing more methane and higher hydrocarbon gases which leads to the formation of bituminous coal. Bituminous coal will experience more pressure and heat which will lead to the formation of anthracite (as shown in Figure 1). South African coal was formed under cold to cool temperature conditions and this has led to the country being dominated by high ash bituminous coal and moderate amounts of anthracite.

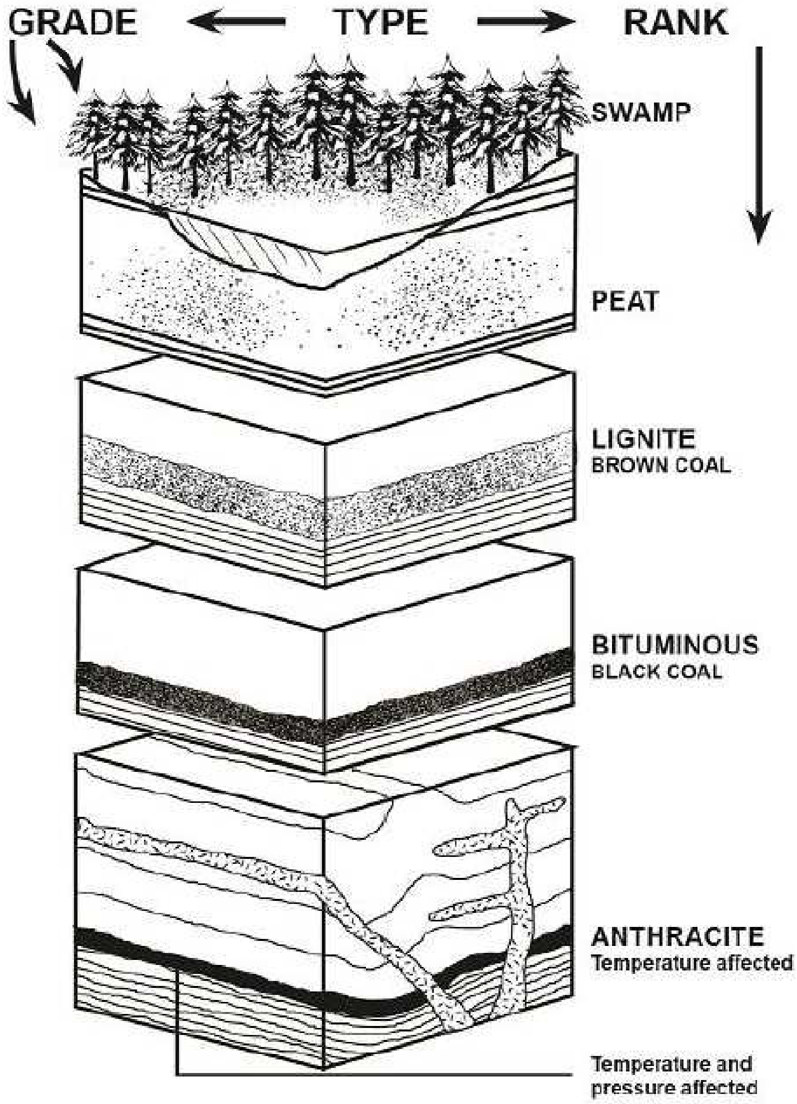

Figure 1: A schematic diagram showing the grade, type and rank of coal.

South Africa has 19 coalfield (as shown in Figure 2) which are distributed on the eastern side of the country, mainly in provinces such as KwaZulu Natal, Mpumalanga, Eastern Cape, Gauteng and Limpopo. The country produces in excess of 258 million tonnes of coal (2014 estimates) which is valued at R102 billion. Out of the 258 million tonnes of coal produced in South Africa, majority of the coal is exported to Europe and Asia/Middle East, and the country consumes almost three quarters of that domestically for power generation, liquid fuel production and metallurgical needs. Around 77% of South Africa's energy needs are derived from coal, 81% of all coal consumed domestically goes towards electricity production and 92% of coal consumed on the African continent is produced in South Africa. South Africa has 15 coal power stations with 13 distributed around the Mpumalanga province and 2 in the Limpopo province (as shown in Figure 2). The coal power stations are owned by a government state owned company called Eskom.

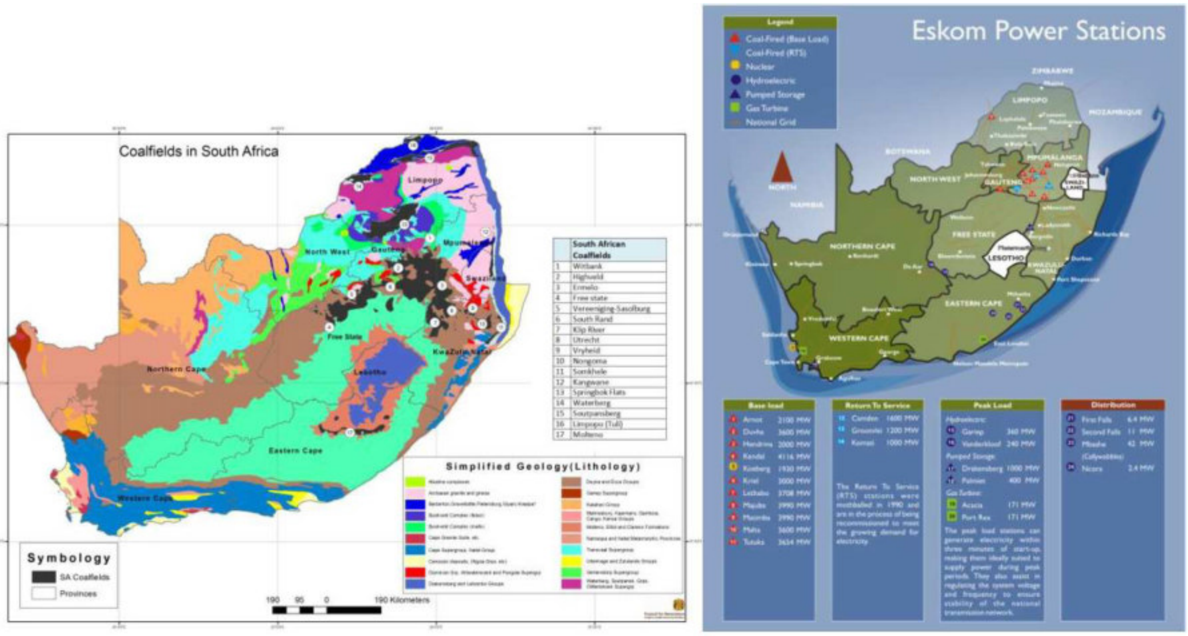

Figure 2: Distribution of Coalfield and Coal fired power stations in South Africa.

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Education:
Bachelor of Science, University of Algiers (1978)
Doctorat 3ème Cycle (Master) in Neotectonics, University Paris 7 (1982).
Doctorat d'Etat (Ph.D) in Neotectonics, Seismotectonics and Paleoseismology, University of Paris 11, Orsay (1988).

Career:
- Researcher, Head of the Active Tectonics Department, Geophysical Centre of Algiers (1988-1993).
- Associate Researcher, University of Paris 11 (Orsay) and Cergy-Pontoise (1994-1995).
- Research Fellow, Royal Observatory of Belgium (1995-1996).
- Research Fellow, National Research Council of Italy (1996-1999).
- Senior Researcher in Active Tectonics at the IPGof Strasbourg, France (since 1999).

Research Interests:
1. Active tectonics and paleoseismological study along the El Asnam thrust fault (associated with M 7.3 earthquake in 1980, Algeria) which is among the first analyses worldwide of coseismic thrust-related surface faulting and folding.
2. Pioneering works in the identification of active faults in intraplate Europe and the Rhine graben with development of paleoseismic studies in regions with low-level of seismicity. In particular, combining the use of micro-topography, shallow geophysics and trenching in active faulting studies.
3. Development of earthquake geology, paleoseismic and archeoseismic studies in different tectonic domains (North African Atlas, North Anatolian fault, East Anatolian fault and Dead Sea fault) and comparison between regions with slow active deformation and regions with fast seismic slip release.
4. Conceptual framework in the understanding of the long-term faulting behavior in earthquake-prone regions, coastal tectonics and seismic sources of tsunami. Studies of faults in regions with the potential for large or moderate earthquakes and related physical characteristics.

Publications and Services

Meghraoui, M., and K. Atakan, 2014, The contribution of paleoseismology to earthquake hazard evaluations, in *Earthquake hazard, risk and disasters*, book edited by M. Wyss, Chapter 10, 237-271, Elsevier, London.

Meghraoui, M. Paleoseismic history of the Dead Sea fault zone, in Encyclopedia of Earthquake Engineering, 2015.

Meghraoui, M., P. Amponsah, A. Ayadi, A. Ayele, B. Ateba, A. Bensuleman, D. Delvaux; M. El Gabry, R.-M. Fernandes, V. Midzi, M. Roos, and Y. Timoulali, 2016, The Seismotectonic Map of Africa, *Episodes Vol. 39, no. 1, DOI:10.18814/epiiugs/2016/v39i1/89232*

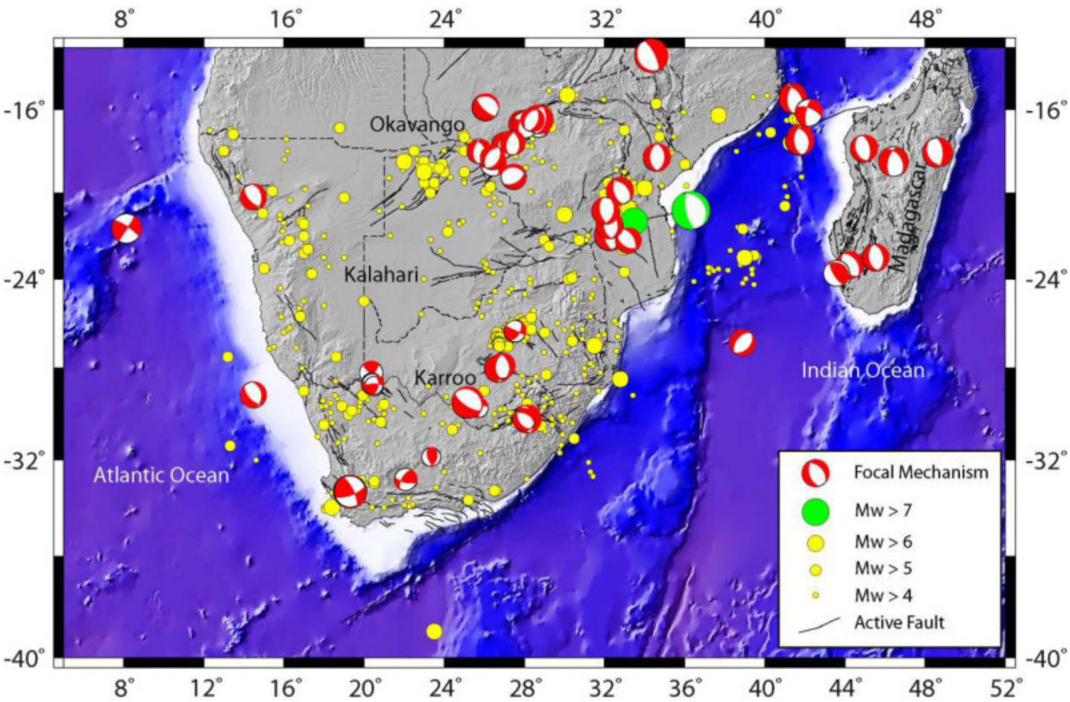
Awards and Honours

- « Merit Award » from the Italian Ministry of the Interior for the scientific contribution following the September-October 1997 Colfioritoseismic sequence in the Umbria-Marche.
- « Honour Award » from the Geological Society of Turkey (61st Geological Congress of Turkey, 24-28 March 2008) for the contributions on active tectonic studies in Turkey.
- Member of the Algerian Academy of Science and Technology (AAST since July 2015).

Earthquake faulting and implications for the seismic hazard assessment in Africa

Mustapha Meghraoui
University of Strasbourg, France

Earthquake geology is a relatively young method of earthquake studies at the interface between tectonic and seismology. Field investigations in earthquake geology have enriched the fault rupture database in some active zones (e.g., California, Turkey, Italy, North Africa, EastAfrican Rift System) and contribute to a significant progress in the concept of earthquake cycle and seismic hazard assessment.The course will address the issue of earthquake activity and importance of seismotectonic characteristics for the seismic hazard assessment in Africa. The physics of earthquake ruptures determine the fault parameters to be taken into account in any seismic hazard and risk assessment. The seismic moment defines the dimension of coseismic rupture and related coseismic slip in the brittle seismogenic layer of the lithosphere. The identification of slip distribution along surface faulting during a shallow seismic event provides the necessary parameters for a proper estimation of the moment-magnitude Mw. The rate of earthquake deformation (GPS) and rate of fault slip are to be compared to the repetition of earthquake faulting and field analysis (trenching) in paleoseismology.Models of fault behavior include late Pleistocene and Holocene cumulative coseismic slip that illustrates the long-term earthquake activity. The seismotectonic characteristics of active zones includes the fault kinematics and stress distribution using mainly focal mechanism solutions. With the seismicity catalogue and analysis of earthquake faulting, the seismic zoning is the basis for the earthquake hazard evaluation.



Seismotectonics of southern Africa(1900 – 1912; Midzi et al., 1999; Singh et al., 2009), an excerpt of the Seismotectonic Map of Africa (Meghraoui et al., 2016).

Earthquake prone areas of the African continent includes plate boundary zones (Northwest Africa and EARS) and intraplate tectonic domains (plate interiors). Except for some regions with dense GPS network (e.g., Morocco, Ethiopia-Djibouti) and extensive studies on earthquake faults (northern Algeria and some sections of EARS), the rate of active deformation is roughly known across the continent. Some tectonic domains often qualified as stable in Africa turns out to be seismically active and site of damaging earthquakes. The occurrence of the 4 December 1809Milnerton (Ms 6.3) and 29 September 1969 Ceres-Tulbagh (Ms 6.3)and 5 August 2014 Orkney (M_L5.5) earthquakes in South Africa Investigating the rate of earthquake activity and related seismic cycle in plate interiors such as in South Africa is a challenging task. This earthquake activity and its implications for the seismic hazard assessment will be discussed during the course.

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Midzi V., Hlatywayo, D. J., Chapola, L, S., Kebede, F., Atakan, K., Lombe, D.K., Turyomurugyendo, G., Tugume, F., 1999.Seismic Hazard assessment in eastern and southern Africa, Annali Di Geofisica, 42, (No. 6), 1067-1083.

Singh, M., Kijko, A. and Durrheim, R. (2009). First order regional seismotectonic models 19 for SA, Natural Hazards, *DOI 10.1007/s11069-011-9762-3.*

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Education:
B.Sc. (Honours) *cum laude* (Wits, 1985); Ph.D. (University of the Witwatersrand, 1992); Post-doctoral Fellow (Harvard University, 1997-1998).

Career:
1995-2016: Senior Research Officer, Economic Geology Research Institute; School of Geosciences, University of the Witwatersrand. Visiting Fellow: Harvard University (1997-98); Visiting Researcher: ITC Enschede (Netherlands) (1997); GFZ (Potsdam) and MfN (Berlin) (Germany, 2015); University of California, Riverside, CA (USA, 2016).Published papers >60; H-index 14.
1994. Consulting Geologist, Environment and Remote Sensing Institute, Harare, Zimbabwe.
1980-1994: Mine, Exploration, and Research Geologist with MTD (Mangula) Ltd; Mhangura Copper Mines Ltd; Alaska Mining and Smelting Ltd., Zimbabwe.

Research Interests:
Stratabound Sediment-hosted Copper Deposits; Regional geology and metallogeny of Africa; Meteorite impact structures, Proterozoic carbonate chemostratigraphy; Palaeotsunamites, History of Science.

Publications and Services
Master, S. and Valli Moosa, M. (2015). Large imbricated megaboulder bed in Bantry Bay, Cape Town- results of a tsunami induced by bolide impact on the continental shelf? Extended Abstracts, 14th South African Geophysical Association Biennial Technical Meeting and Exhibition, Drakensberg, South Africa, 7-9 September 2015.

Master, S. (2014). A note on imbricated granite boulders on NW Penang Island, Malaysia- tsunami or storm origin? In: Kontar, Y., Santiago-Fandiño, V., Takahashi, T. (Eds.), *Tsunami Events and Lessons Learned: Ecological and Societal Significance.* Springer- Science+Business Media, Dordrecht, the Netherlands, 225-241.

Master, S. (2011). Transported megaboulders and the recognition of palaeotsunamites at Clifton Beach and surrounding areas, Cape Town, South Africa. Abstract,, GeoSynthesis 2011, 30/8- 1/9 2011, Cape Town, South Africa, 188-189.

Master, S. (2005). Tsunamis: Past, Present and Future. Abstract Volume (CD-ROM), Geo2005 International Conference, 3-7 July 2005, Durban, KwaZulu-Natal, South Africa, 138-139.

Awards and Honours:
Order of the Golden Boot, Palaeontological Society of Southern Africa (2016)
Honorary Membership of the Geological Society of Zimbabwe (2016)
Carnegie Large Research Grant, Carnegie Corporation, New York (2011)
A.E. Phaup Award for Best Paper on Zimbabwean Geology (2010), Geol. Soc. Zimbabwe
Harvard-South Africa Fellowship, Harvard University, Cambridge, MA, USA (1997-1998)
Gencor Prize for Best Geology Honours Student (1984) at University of the Witwatersrand

Tsunamis in Cape Town
Sharad Master

Introduction: Until December 26th 2004, when the great Indonesian earthquake off Sumatra triggered one of the most devastating natural disasters in human history, few people had heard of a "tsunami", and fewer still knew what it meant. Tsunami is a Japanese word, derived from *tsu* = harbour, and *nami* = wave; hence a tsunami is a special kind of sea wave. The most famous Japanese print is Hokusai's depiction of a great wave off Kanagawa (Figure 1), widely believed to be an illustration of a tsunami. Contrary to a popular misconception, a tsunami is *not* a tidal wave. In this presentation I will first discuss what tsunamis are, and what causes them. Then I will look at the evidence that ancient tsunamis may have lashed the coastline around Cape Town.

Figure 1: *"In the hollow of a great wave off Kanagawa"* by Hokusai Katsushika (1760-1849).

What causes tsunamis?: Tsunamis are produced when huge volumes of water are displaced suddenly by catastrophic, highly energetic events in the oceans, such as: (1) undersea earthquakes or "seaquakes", (2) large undersea landslides, (3) undersea explosive volcanic eruptions, and (4) asteroid or comet impacts in the oceans [1,2]. The energy from these catastrophic events is dispersed in the form of waves, similar to ripples in a pond. The velocity of the wave, $v = \sqrt{gh}$, where g is acceleration due to gravity (9.8 ms^{-2}), and h is water depth in m. In the open ocean, where the depth is 2 km, tsunami waves can travel at about 500 km/hr. These fast waves typically have a wavelength of the order of a km, and low amplitudes, ~1 m. As water depth decreases, the velocity decreases, but the frequency and the amplitude of the wave increases, with the most energetic waves being 10's of m high (Figure 2).

Tsunamis triggered by submarine earthquakes: These are the best-known kind, and include the Indian Ocean tsunami triggered by a large (magnitude 9) earthquake off Sumatra on 26 December 2004. The Sumatran earthquake was located along a major plate-boundary fault located along a subduction zone between the Australian-Indian and Asian tectonic plates. The fault was 1200 km long (extending to the Andaman Islands; Figure 3a), and was displaced vertically by up to 10 m along its length [3]. The 26 Dec. 2004 tsunami affected 12 countries around the N Indian Ocean (Figure 3b), and resulted in around 300,000 human deaths, as well as leaving ca. a million people homeless. It was one of the most destructive tsunamis in human history [4].

On 11 March 2011, a magnitude 8.9 earthquake occurred, having its epicentre on the ocean floor NE of Tohoku, Japan. This massive earthquake triggered a colossal tsunami, which destroyed much infrastructure on the Tohoku coastline, including disabling the Fukushima Dai-Ichi Nuclear Power Station, and to the leak of nuclear radiation, and the evacuation of thousands of people, in the largest concatenated natural disaster in modern Japan.

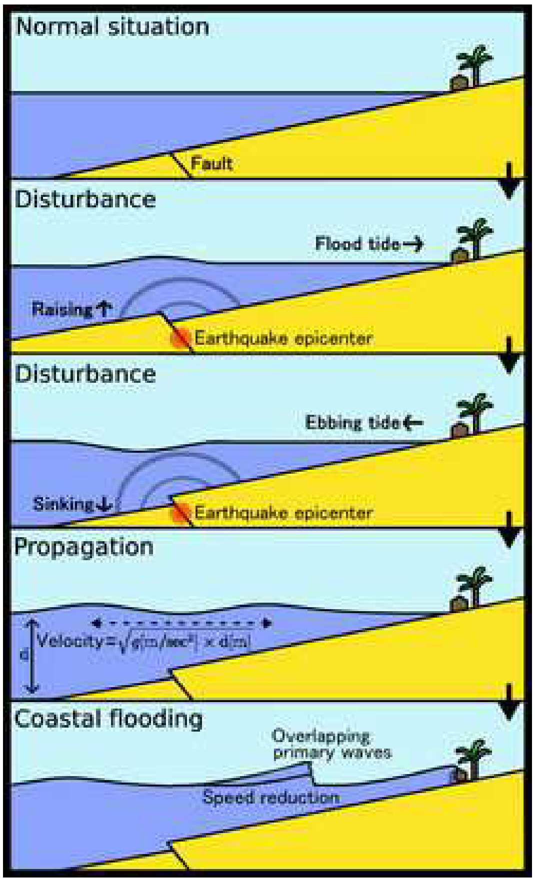

Figure 2: Schematic representation of a tsunami generated by a submarine earthquake [2].

The geographer Strabo (24 BC-c.23 AD), gives graphic descriptions of tsunamis generated by earthquakes in ancient Greece [5]. Better documented historic tsunamis triggered by earthquakes include the tsunami following the 17 February 1674 earthquake in Ambon in the Moluccas, Indonesia [6], the North Atlantic tsunami following the 1755 Lisbon earthquake, and the Pacific Ocean tsunamis triggered by earthquakes in Chile (1960), and Alaska (1964).

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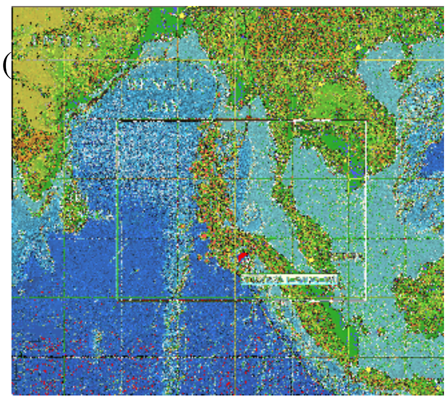

(b)

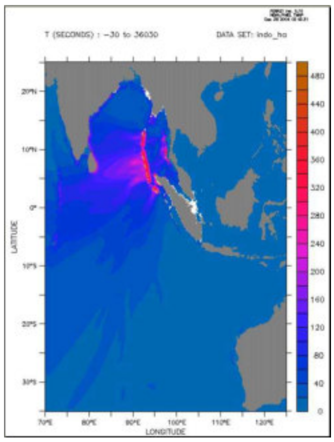

Figure 3: (a) Epicentres of M9 26 Dec. 2004 earthquake and aftershocks on 1200 km fault segment of Sumatran-Andaman subduction zone [3]. (b) Paths and heights of the tsunami generated by the 26 Dec. 2004 earthquake.

Tsunamis triggered by submarine landslides: Submarine landslides occurring off the continental shelves can mobilise huge volumes of sediment, and can displace equally huge volumes of water catastrophically, generating large tsunamis. The best known examples of these are the Storegga slides which occurred off the Norwegian continental shelf between 5000 and 50,000 years ago [7-9]. The most recent major submarine landslide-triggered tsunami killed several hundred people in Papua New Guinea in 1998 [9]. A potential future collapse of the Cumbre Vieja volcano on La Palma in the Canary Islands could result in a landslide of 500 km^3 volume, which could generate a massive megatsunami with the potential to devastate the entire North Atlantic seaboard, affecting millions of people [11].

Tsunamis triggered by submarine explosive volcanic eruptions: Catastrophic explosive undersea volcanic eruptions, of intermediate (andesitic-dacitic) volcanoes found along subduction zones in island arc settings, can trigger large tsunamis. The most famous example is that of the Indonesian volcano Krakatau, which in 1883 exploded violently and then underwent a catastrophic caldera collapse which triggered a devastating tsunami that wiped out 295 villages and killed 36,380 people. In c. 1650 BC, during the Minoan Bronze-age, the explosive phreatomagmatic eruption and subsequent collapse of the volcano Santorini in the Aegean Sea, Greece, generated huge tsunamis, which lashed the north coast of Crete, destroying port cities of the Minoan empire [12].

Tsunamis triggered by oceanic asteroid/comet impacts: Unlike the case with earthquakes, asteroid or comet impacts in the oceans have no upper limits to their energy, and can potentially generate the most energetic and destructuve tsunamis on earth. Some of the oldest and most powerful tsunamis in the geological record, dating from 3.47 to 2.47 Ga, were generated by such impacts [13]. A postulated impact in southern Iraq in the 3rd Millenium BC may have produced tsunamis which wiped out Mesopotamian cities, and engendered the flood myth in the Epic of Gilgamesh [14,16]. It has recently been proposed that an asteroid struck the Southern Ocean in c. 1800 BC, generating a megatsunami which gave rise to flood legends around the world [15,16]. In historic times, the Mahuika impact on the continental shelf off New Zealand, in c. 1500 AD, produced tsunamis which lashed the nearby shores of Australia and New Zealand, which are recorded in Aboriginal and Maori legends [17].

Tsunamis in Cape Town: The northwestern part of Cape Town's Atlantic seaboard, stretching from the suburbs of Bantry Bay, through Clifton to Camps Bay, contains some of the most exclusive and desirable residential properties in Africa. This coastal stretch is characterised by prominent outcrops of megacrystic granite of the c. 540 Ma Cape Granites of the Peninsula Batholith. These granites are topped, in the high mountains around Cape Town, with quartzites of the Ordovician Table Mountain Group of the Cape Supergroup. Master (2011) [18] presented evidence that this stretch of coastline has been subjected in the prehistoric past to huge waves, resulting from storms or tsunamis, which had sufficient energy to have lifted and transported numerous massively large granite boulders, with masses ranging from a few tons up to 150 tons. The evidence includes megaboulders which have been transported onto other rocks; slabs which have been plucked and rotated, and exfoliated granite slabs which have been stacked in an imbricate fashion (cf [20]. Among the criteria used to determine if large boulders have moved is the presence of large unjointed granite boulders overlying mafic dykes (Figure 4), and/or joints in granites. While this evidence points to the agency of large waves, it does not diagnostically discriminate between a tsunami or storm origin.

Nandasena et al. (2011)[20] have given revised hydrodynamic equations to determine the minimum velocities needed to transport boulders under various modes of transport- sliding, rolling, and saltation. Master (2014)[19] used these to show that imbricated boulders on Penang Island, Malaysia, could not have been moved by the tsunami of 26 December 2004, but that they probably moved as a result of a tropical storm. Master and Valli Moosa (2015)[21] found a new imbricated megaboulder bed in Bantry Bay, Cape Town, and they made hydrodynamic calculations, based on [20], which give the minimum flow velocities needed to generate such a bed.

Because the boulders are imbricated, resting upon each other like tiles in a roof, the minimum velocity needed to move the largest boulder in rolling mode is normally taken as the minimum velocity to move all the boulders together [19]. However, unlike normal imbricated boulders produced by rolling, in which the longest dimensions of the boulders are aligned perpendicular to the flow direction, in this boulder bed, the azimuths of the long axes are parallel to the flow direction and could not have been produced by rolling. Hence the transport regime for the boulders was deduced to have been one of

Figure 4: 70 tonne boulder, overlying a weathering slot over a 1.2m wide Cretaceous dyke of the False Bay dyke swarm. Located between Fourth Beach and Moses Beach, Clifton, Cape Town.

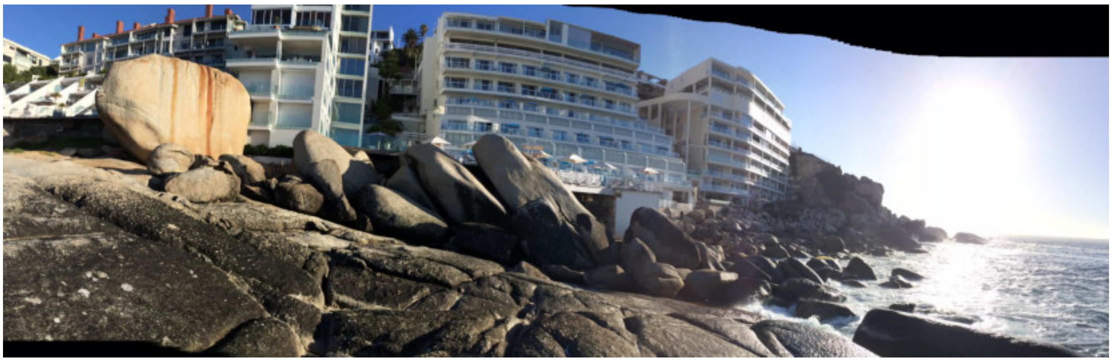

Figure 5: Imbricated magaboulder bed on the shoreline, Bantry Bay, Cape Town. The largest imbricated boulder, in the centre, weighs about 265 tonnes.

saltation, with boulders having violently slammed together after having been lifted by huge waves [21]. Therefore the saltation mode transport equations were used to determine the minimum velocities of flow needed. In practice, this meant calculating the minimum velocity needed to move the largest of the boulders, which is wedged in between several smaller boulders which had to be transported by the same wave. The results of the calculations for the largest granite boulder, which is 10m long, 5 m wide, and just under 2 m thick, and weighs about 265 tonnes, give a minimum velocity of seawater flow of $U \geq 18$ m/s to transport the boulder in saltating mode [21]. By comparison, the velocity of the incoming tsunami wave of the Great Indian Ocean Tsunami of 26 December 2004, after runup, as recorded on Batu Feringgi beach on the north coast of Penang Island, Malaysia, was about 3.3 m/s [19]. The calculated wave velocity of ≥ 18 m/s needed to transport the Bantry Bay boulders rules out a seismogenic tsunami originating from the nearest subduction zone in the South Sandwich Islands, as well as tsunamis induced by landslides on the continental shelf, which are themselves triggered by seismicity, which is lacking on the South Atlantic margins [21]. Thus it is more likely that the megaboulder bed was produced by tsunami waves resulting from bolide impact in the ocean, a process for which there is no upper energy limit, unlike for seismogenic tsunamis [21].

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[2] http://en.wikipedia.org/wiki/Tsunami.
[3] http://tsun.sscc.ru/tsulab/20041226.htm
[4] http://hompage. mac.com/demark/tsunami/8.html; http://www.ess.washington.edu/tsunami.
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Education:
MS.c in Environmental Science from the University of KwaZulu Natal, the theses was on "*spectral differentiating Cannabis Sativa L from Maize using hyperspectral Indices*". BS.c Honours degree from the University of Fort Hare, my thesis was on "*Comparing SRTM X band DEM with conventional DEM for use in fracture mapping and analysis on hydrological studies*".

Career:
In 2012 I joined the South African National Space Agency (SANSA) as a remote sensing scientist focusing on the development of value added products for disaster management. In the past three years while working at SANSA, I developed a novel method of mapping snow cover using LandSat 8 dataset. In addition, I also developed the flood potential map of South Africa using the Shuttle Radar Topography Mission (SRTM) 30 metre data which is critical in flood predictions and modelling. I also worked for the Agricultural Research Council, institute for soil climate and water (ARC-ISCW) as a researcher from 2006 to 2012,my core responsibilities were on remote sensing applications on agriculture focusing on predicting crop yield, crop growth and health monitoring.

Research Interests:
Flood prediction,flood monitoring and flood risk modelling.

Publications and Services:

- Sibandze, P. Mhangara, P. Odindi, J. Kganyago, M (2014) a comparison of Normalised difference Snow Index (NDSI) and Normalised Difference Principal Component Snow Index (NDPCSI). South African Journal of Geomatics, Vol. 3, No.

- Sibandze, P. Mutanga, O. Cho, O. Newby, T. Mangara, P (2013) Spectral differentiation of cannabis Sativa L from maize using carotenoid indices. Proceedings of the EARSel Workshop on spectroscopy, Nantes France.

Remote sensing and natural hazards – the FUNDISA software and the ESA School Atlas

Remote Sensing is one of the most important technologies that provide information to the disaster authorities before, during and after a disaster. In their nature, disasters go through a life cycle, the information gathered through Geographic Information Systems (GIS) and the Remote Sensing of the environment aid in preparing, recovering, responding and lessening the impact of a natural hazard to society. These technologies offer the capability to monitor the build-up of gradually occurring and catastrophic disasters such as drought and floods respectively. It is therefore important to create awareness and build capacity in the use of remote sensing for mapping, monitoring and modelling natural hazards. The Fundisa disk is one of products developed by the South African National Space Agency (SANSA) which provides open-source GIS and remote sensing tools for research and developing remote sensing applications like the mapping of natural hazards. In addition to the software, the disk also have tutorials ranging from basic interpretation of satellite images to more advance applications like modelling areas vulnerable to flooding.

Tsholofelo Diphoko is a GIS Specialist at Esri South Africa. She received her BSc Honours degree in Geography from the University of Witwatersrand in 2012. Since arriving at Esri South Africa she has taken over the position of Education Consultant. Her role includes travelling to various parts of the country creating awareness in Geography and most importantly being involved in the FundaLula programme. The job includes development of content, training teachers and business development amongst other things. She is passionate about GIS as a career path and intends to increase the awareness of its wide variety of use in every possible way

FundaLula: Mapwork with GIS - The new way to master Mapwork

FundaLula is Esri South Africa's education product aimed at making Mapwork easier.

Esri South Africa has developed an application that covers every component of the Mapwork curriculum. The application is designed to equip teachers and learners with skills to master Mapwork using GIS in order to convey fundamental concept
FundaLula aims to develop geospatial critical thinking, reasoning, investigative & creative skills that learners can use in all areas of their lives.

John Ludden

Prof.

BGS Executive Director

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Summary

Executive Director at the British Geological Survey and an Executive member of the Natural Environment Sciences Research Council, UK, since 2006, John has held numerous science direction and management posts. Prior to this he was Director of the Earth Sciences Division at the French National Centre for Scientific Research (CNRS) and a Director of Research (classe exceptionelle) for the CNRS in France, where he also taught at the French National School of Geology (ENSG-Nancy). He has a broad understanding of Earth and environmental sciences and science in general, with specialist knowledge in geochemistry. He has extensive experience in developing the research agendas of universities and the public sector along with experience in translation of research to innovation. He worked as a professor and research scientist at the University of Montreal, Lamont Doherty Earth Institute of Columbia University and with Woods Hole Oceanographic Institution in the USA and holds a doctorate from the University of Manchester, UK. He has visiting and honorary professor status at several universities and is a Foreign Member of the Russian Academy of Sciences and past president of the European Geosciences Union and also EuroGeosurveys. He has published extensively in specialised science journals and also in popular science http://scholar.google.co.uk/citations?user=05oOqAIAAAAJ&hl=en

Lighting up the subsurface

John Ludden
British Geological Survey

Our future use of the subsurface, particularly for energy (subsurface gas storage, compressed air energy storage, shale gas, coal bed methane, underground coal gasification, enhanced oil recovery, geothermal) and waste disposal relating to energy (carbon capture and storage, radwaste),but also for mineral resources, depends on much greater understanding of subsurface flow and processes. This is particularly pertinent to low-carbon energy because the feasibility of three low carbon energy solutions rely on understanding of subsurface geological containment or flow: carbon capture and storage (CCS), shale gas and radwaste. Mineral deposit development and extraction, particularly near urban areas must be mined responsibly. Lack of understanding and uncertainty feeds through to lack of confidence amongst policy makers and industrial investors, and most of all to lack of public confidence.

We propose an infrastructure "the Energy Test Bed" to allow the subsurface to be monitored at time scales that are consistent with our use of the subsurface, to increase efficiency and environmental sustainability but also to act as a catalyst to stimulate investment and speed new technology energy and mining options to commercialisation.

1. the impact of deep shale gas drilling and hydraulic fracturing on shallow groundwater and surface water, on seismic activity, and on ground stability and subsidence;
2. processes relating to the containment, confinement, and rates of solution and carbonation of subsurface stored CO_2 in carbon capture and storage;
3. processes relating to the containment and confinement of subsurface nuclear and other types of waste; movement of fluids (gas, water, solutes);
4. studies on the impact of coal combustion products on the environment both from surface and subsurface operations (e.g. underground coal gasification);
5. the role of biological mediation in the subsurface in shallow to deep environments;
6. processes at basin and reservoir scale in reservoir stimulation and enhanced oil recovery (EOR);
7. ground deformation and induced seismicity associated with enhanced geothermal systems in hot-rock-dry-rock environments.
8. Large subsurface and open surface mining operations and associated waste management

We will develop a unique package of monitoring capability where monitoring at the surface and in the critical zone will be coupled with deep borehole monitoring of variables such as pressure, temperature, heat flow, seismicity, tilting, strain accumulation, fluid chemistry, pH and biological properties. Monitoring will also include satellite and remote sensed data such as InSAR (Interferometric synthetic aperture radar) and gravity, electrical, spectral and magnetic data.

Infrastructure that underpins research into subsurface activity will make us better at monitoring and managing these new and continuing activities safely and sustainably, including optimising exploration practices. Industry would benefit in being able to access state-of–the–art monitoring data to maximise efficiency of extraction and subsurface management, as well as maximising environmental sustainability.

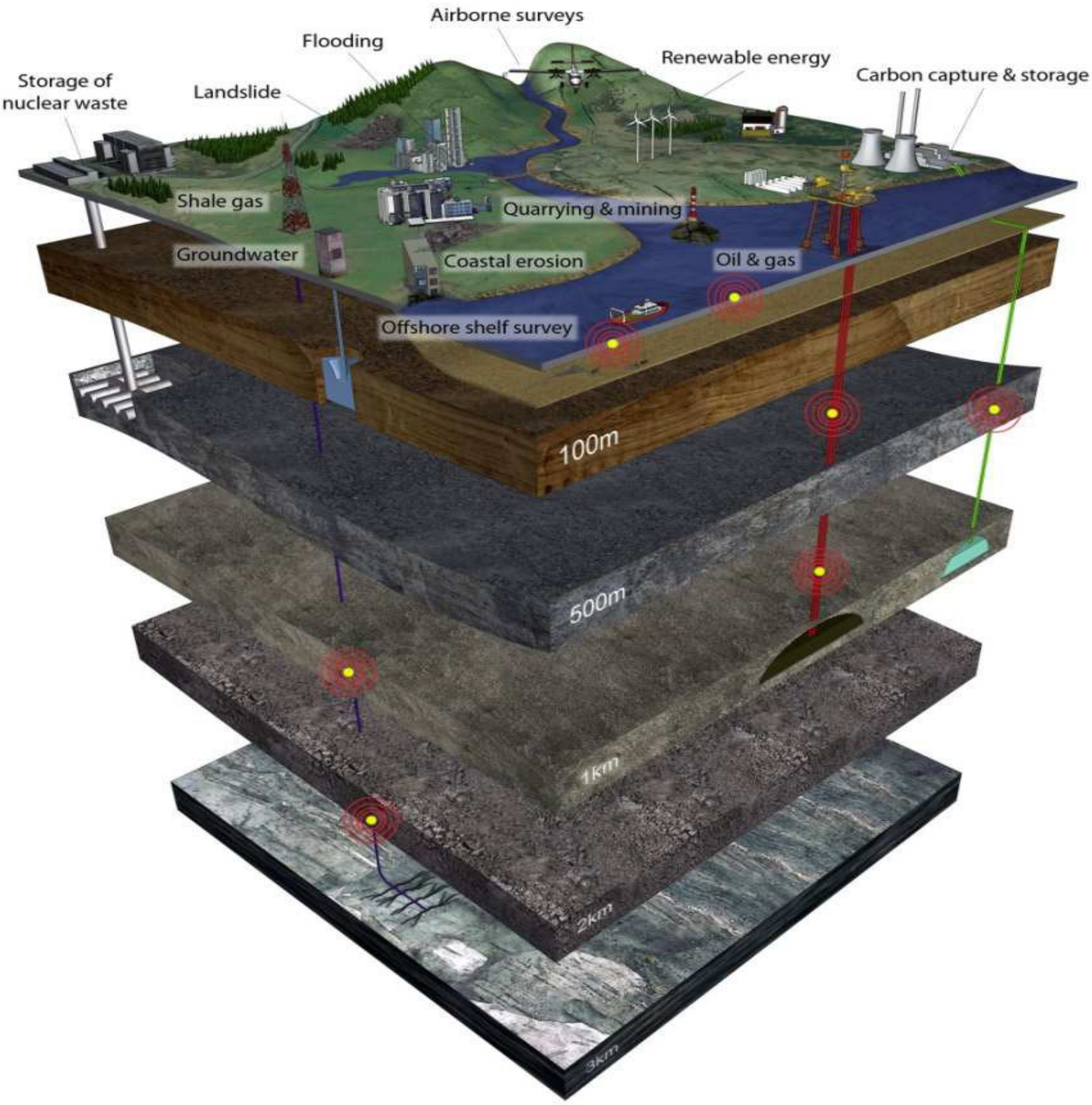

Figure 1 Schematic model of the "energy test bed"

The **economic impact** is potentially very large in developing (1) untapped energy resources like shale gas, CBM, UCG, geothermal and new occurrences; (2) methods to sustain fossil fuel reserves e.g. EOR; (3) understanding of storage processes including CCS, gas storage and radioactive waste disposal; and (4) subsurface energy storage such as compressed air energy storage (CAES). Economic value will also stem from management and minimisation of environmental impacts which will protect the environment, ecosystem services, property and infrastructure.

Greater understanding of subsurface processes, if communicated properly, will also allow better public buy-in to subsurface usage and therefore more efficient, streamlined development.

The **scientific impact** of this new infrastructure will be far reaching, including understanding of subsurface flows, geochemistry and physics of rock matrices, and the interaction of surface carbon and other geochemical cycles and subsurface flows.

The new infrastructure will act as a catalyst for industry both onshore and offshore to stimulate investment and speed new technology options to commercialisation. It will thus act as a bridge from ideas to application and would attract support and possible co-funding from oil and gas companies, mining companies, utilities and energy and environment consultancies.