THE GEOPARKS NETWORK AND
INTERNATIONAL GEO SCIENCE PROGRAMME

INVOLVEMENTS BY CGS, GSSA & OTHERS IN THE PAST AND PRESENT

45th NSTF Plenary Meeting on 6 June 2014

Outline of the Presentation

- Geopark, its advantages, Global Geopark Network
- Criteria to be met for a Geopark
- SA Initiatives for establishing first Geopark
- Geosite database for SA by CGS
- Promotion of Geoheritage in the Cape (through GSSA and 35th IGC)
- Developments in SA on Geoheritage, Geotourism & Geopark Initiatives
  - Potential of Western Cape for Geoparks
  - Potential of a Geopark in the Gauteng
  - Geotourism in the Limpopo, Mpumalanga and Eastern Cape
  - The potential for proclaiming a Wild Coast Geopark
  - Uniqueness of RSA for Geoparks and Actions Needed
- African Geoparks Network
- International Geoscience Programmes
  - CGS Involvements in IGCP
  - Other relevant CGS projects forming input for the IGCP themes
What is a Geopark?

- A Geopark is “a territory encompassing one or more sites of scientific importance, not only for geological reasons but also by virtue of its archaeological, ecological or cultural value” (UNESCO International Network of Geoparks). Geopark is a territory, in which geological heritage is protected and managed in a sustainable manner.
- In practice, the Geopark is an initiative that can achieve international recognition for geological sites of local and regional importance.
- The Geoparks are becoming very popular due to their combination of conservation, sustainable development and community involvement.
- It has the potential to be part of a global network which demonstrates and shares good practices for preservation of Earth’s heritage and its involvement in strategies for sustainable development.
- Geoparks are not a legislative designation though the key heritage sites within a Geopark should be protected under local, regional or national legislation as appropriate.
Advantages of Geoparks

- Geoparks provide opportunities for studying of geology and other natural sciences.
- Many Geoparks promote awareness of geological hazards, including volcanoes, earthquakes and tsunamis and many help prepare disaster mitigation strategies among local communities.
- Geoparks hold records of past climate change and are educators on current climate change as well as adopting a best practise approach to utilising renewable energy and employing the best standards of “green tourism.”
- Geoparks also inform about the sustainable use and need for natural resources, whether they are mined, quarried or harnessed from the surrounding environment while at the same time promoting respect for the environment and the integrity of the landscape.
Global Geoparks

A Global Geopark is a unified area with geological heritage of international significance.

As of January 2014, there are 100 Global Geoparks spread across 30 countries.

The Global Geoparks have until recently been concentrated in Europe and in China (29 Geoparks).

However, the last few years have seen the geoparks initiative spread worldwide so that there are existing Global Geoparks, or active applications to become Global Geoparks, on all continents.

Source: UNESCO website
The Global Geoparks Network (GGN) (also known as the Global Network of National Geoparks) is a voluntary network of Global Geoparks supported / assisted by UNESCO (established in 1998) and is managed under the body’s Ecological and Earth Sciences Division.

The GGN is a dynamic network where members are committed to work together and exchange ideas of best practice and join in common projects to raise the quality standards of all products and practises of a Global Geopark. The GGN functions through the operation of regional networks and comes together every two years.

Source: UNESCO website
Set of criteria to be met for a Geopark as established by UNESCO

• A set of criteria as established by UNESCO must first be met for a geopark, as nominated by the corresponding government, to be included in the GGN:
  – the existence of a management plan designed to foster socio-economic development that is sustainable (most likely to be based on agritourism and geotourism);
  – demonstrate methods for conserving and enhancing geological heritage and provide means for teaching geoscientific disciplines and broader environmental issues;
  – joint-proposals submitted by public authorities, local communities and private interests acting together, which demonstrate the best practices with respect to Earth heritage conservation and its integration into sustainable development strategies.

• Criteria satisfaction is evaluated during biennial meetings (every even year) by the Geoparks Committee, known as the International Conference on Geoparks, which is also in charge with the periodic review of projects related to geological awareness.
One of the youngest identified impact craters on Earth, being approximately 220 000 years old. It is situated about 50 km north-west of Pretoria, in a densely-populated area, with very good access routes.
Tswaing Meteorite Impact Crater

- Tswaing crater is 1.13 km in diameter and 100 m deep, situated in the central, acid phase granites of the Bushveld Complex that form part of the Nebo Granite.
- It has salt deposits and a highly saline pond in its centre, which gave rise to the name Tswaing (“place of salt”).
- The site is situated on a 2 000 hectare farm and is already recognized as a protected area and managed as a museum by the Northern Flagship Institute (NFI).
- Tswaing is currently on the tentative list for consideration as a World Heritage Site.
Since Tswaing is already managed by a recognized organization, the establishment of a Geopark at the site should be so much easier.

The NFI Management Board has already approved the efforts to establish a Geopark at Tswaing. However, financial problems are prohibiting the installation of a modern impact museum, as is planned (financial difficulties proves to be a real obstacle).

Another problem specific to South Africa, is to find an authority to take ownership of the South African Geosites. Some organization needs to oversee the proper management of such sites in South Africa.

An additional cause of concern is that no equivalent body to, for instance, English Nature exists in South Africa to drive the establishment of Geosites.

The only formal body currently in existence is the Geoheritage Committee of GSSA. However, the members of this Committee are volunteers and, as such, have their own permanent jobs and all the work needed to drive the aims of the Committee must be done in their private time.
Geosites Database for South Africa (also covering SADC region)

- Online database of geological sites in Africa was initially developed by the Council for Geoscience (CGS) in South Africa (Roger Price & Dani Bernardo).
- A total of 121 described geosites are already available via the Internet [http://196.33.85.17/geosites/](http://196.33.85.17/geosites/). These sites are located mainly in South Africa, as well as in Zimbabwe and Lesotho.
- It is also possible for contributors to register new Geosites on the system via the Internet.
- A sophisticated query and output system forms part of the site and allows a list of all or selected records in the database to be selected and output obtained in either PDF or html format.
- It is maintained by the CGS.
Promotion of Geoheritage in the Cape by GSSA

- The Western Cape Branch of the Geological Society of South Africa (GSSA) has been involved in promoting public understanding of the geoheritage of the Cape since the Seventies.
- The Geoheritage Subcommittee, formed in the Nineties, produced a number of printed brochures and erected plaques at geologically interesting locations around the Cape.
- Building on this initiative, the present subcommittee, consisting of Doug Cole, John Rogers, Coenie de Beer, Claire Browning, Len Gardner, David Le Roux, Dave Roberts etc., have been working to review and modernise these brochures for distribution on the Internet.
- The first brochure, Paarl Mountain, has been uploaded onto the branch website as the first in a series “Cape Geosites”. Information from the brochure has also been posted as a Wikipedia article.
Mining of diamondiferous gravels from ancient storm beaches – West Coast

Table Mountain – Cape Town (a geosite from initial database of CGS)

GSSA PLAQUES – eg. Cogmans Kloof
De Hoop Quarry where blocks of medium-grained granite are extracted by means of feather-wedging.

Younger aplite (fine-grained granite) dyke intruding older porphyritic granite on summit of Bretagne rock.
Geoheritage Initiatives: Cape Geosites Series

- Geoheritage is one of the key focus areas of the 35th IGC. The Western Cape Regional Office of CGS is playing a pivotal role in promoting the establishment of a Global Geopark in the Western Cape as a major legacy of the conference. GSSA Geoheritage is also working on a database for collation of all geosites.

- The GSSA Cape Geosites series is due for completion by 2016 when the next IGC will be held in Cape Town, and some sites may form the basis for the first Geoparks to be launched in South Africa during the conference. The preparation of pamphlets for new sites, including possible new Geoparks, is an on-going process.

- The following Geosites should be released by 2016:
  - Table Mountain*, Sea Point Contact, Chapman’s Peak Drive*, Hout Bay Manganese Mine, Paarl Mountain*, Brandvlei Hot Springs*, Cogmans Kloof*, Oorlogs Kloof* (glacial floor), Gansfontein Palaeosurface (fossil trackways), Langebaan Lagoon and Robben Island.

*: Currently available for download
Geosite Locations in the Cape

- Langebaan
- Table Mountain
- Sea Point Contact
- Chapman’s Peak Drive
- Robben Island
- Hout Bay Manganese Mine
- Paarl
- Brandvlei
- Cogmans Kloof
- Oorlogskloof (Nieuwoudtville)
- Gansfontein Palaeosurface (Fraserburg)
- Manganese Mine
- Robben Island
- Sea Point Contact
- Chapman’s Peak Drive
The Barberton tourism has established the “Barberton Makhonjwa Geotrail” in Mpumalanga Province. They provide guided tours (travel back 3.6 billion years in time along a 37 km trail) on mountain pass between Barberton and Bulembu in Swaziland.

A Geopark initiative was recently sparked by Prof. Richard Viljoen’s appreciation of synergy with the 35th IGC to be held in Cape Town in Aug 2016.

At two meetings organized by Dave Roberts and attended by various interested parties, it was decided to initiate two Geoparks along the southern West Coast centering on the Table Mountain National Park and the West Coast National Park/West Coast Fossil Park/Great Escarpment ~120 km northward. Their inauguration should precede or coincide with the 35th IGC.

A committee including representatives from SAN Parks, CGS, West Coast Fossil Park, GSSA, LOC of 35th IGC as well as other state/parastatal bodies has been set up to carry the process forward. So far the broad boundaries of the 2 proposed geoparks have been delineated and commenced with the application dossier.
Potential of Western Cape for Geoparks
Proposed West Coast and TMNP Geopark fall 100% within a UNESCO Biosphere and World Heritage (Cape Floral Region) respectively.

- So both could be disallowed according to UNESCO policy if prior clearance from the appropriate bodies is not obtained.

A national body to protect these sites is also essential.
Conferences in South Africa on Geoheritage, Geoturism & Geopark Initiatives

- GSSA had organised Geoheritage 2013 Conference held in Oudtshoorn, Western Cape on 8th to 11th September 2013. There were around 29 presentations & 5 Posters and 3 Field Trips (Red Stone Hills & Cango Caves; Kammanassie Trip and Swartberg Circle Route).

- World Heritage and Geotourism Conference June 2009 held in Pretoria (GSSA). Geologists gathered at the Conference argued that geotourism was a business opportunity and that South Africa – considered a unique land of geological superlatives – should recognise and protect its areas of geological significance.

- On 18 and 19 September 2008, a workshop on Geoheritage, Geoconservation and Geoparks was held in the Drakensberg Mountains as a contribution to the International Year of Planet Earth.
Contributions on Geosites Through Books

- **Geological Journeys: A Traveller's Guide to South Africa's Rocks and Landforms** (by Nick Norman & Gavin Whitfield, 2006, 320 pages). This handy volume offers answers and explanations about features along all the major routes across South Africa, and some of the lesser, but geologically interesting, routes too.

- **Geology off the Beaten Track: exploring South Africa's hidden treasures** (by Nick Norman, 09 Dec 2013, 256 pages). It features 13 detailed routes across the country, taking in geologically interesting areas such as the Richtersveld, Cape winelands and the Valley of Desolation near Graaff-Reinet.

Potential of Another Global Geopark Network in RSA

Geological and Mining Heritage of Gauteng

Courtesy: Prof Richard Viljoen
Magaliesberg Quartzite Range with Graben Fault Block
Satellite Image – Bushveld Complex ("BC") (blue) with circular Pilanesberg alkaline volcano
2 060 million years ago these ‘zebra-striped rocks’ were part of an enormous underground pool of molten rock or magma. Slowly, the magma solidified to form an intrusion called the Bushveld Complex that stretches from here to Rustenburg. It is the largest layered intrusion in the world, and contains over half of the world’s chromium, platinum group metals, and vanadium reserves. Here, black layers rich in chromite (a mineral containing ~30% chromium metal) alternate with white layers containing plagioclase (an uneconomic mineral). This association is rare. The good exposure and spectacular splitting of the black layers make this one of the geological wonders of the world; which is why this site has been declared a National Monument.
Worlds largest open cast Pt mine – Plat Reef, Northern Limb of BC
Potgietersrust Platinum Mine (PPRust)
The Vredefort Dome world heritage site encompasses the central part of the oldest and largest meteorite impact site known on earth.

The entire meteorite impact structure (or astrobleme) has a radius of impact of 190 km, while the section designated as a world heritage site features an eroded ‘crater rim' of low hills with upturned quartzite rock strata and other features of the impact.

It is one of about 200 meteorite impact structures currently known on Earth, of which only three have a diameter greater than 150 km.

It is the only world heritage site in Africa that is primarily under private ownership, encompassing 149 farm properties.
Vredefort Dome, South Africa (UNESCO world heritage site)
The Cradle of Human Kind (World Heritage Site)

"Little foot" – one of the most complete skeleton of Australopithecus to date

The latest Australopithecine find (Sediba) from the "The Cradle"
Geotourism Potential in the Limpopo Province

• The province provides a wide range of rock formations from early Archaean crustal rocks (~3 billion years old) to the present quaternary deposits.
• 11 potential geological sites were identified, with several historical mining sites, paleontological sites as well as rock art sites (Ndihvuwo Cecilia Mukosi, 2014).

Complexly folded Sand River Gneiss Suite within the Musina Nature Reserve.

Dolerite dykes crosscutting Sand River Gneiss

Impressive stalactite

Rock art painting at Makgabeng site: Northern Sotho Finger painting of a train as well as human figures
Geopark Potential in Mpumalanga: Blyde River Canyon

- A significant natural feature of South Africa, located in Mpumalanga, and forming the northern part of the Drakensberg escarpment.
- It is 25 km in length and around 750 metres deep.
- It is one of the largest canyons on Earth consisting mainly of red sandstones.

Potholes at Bourkes Luck

The potholes at Bourkes Luck in the Mpumalanga Province are a good example of a well-managed geosite.
The Drakensberg is one of the major mountain ranges of southern Africa with dramatic scenery, high levels of biological endemism, and a concentration of rock art spanning 4,000 years.

The highest reaches of its escarpment feature sheer basalt cliffs, with ramparts of golden sandstone rising above high rolling grasslands, rocky gorges and pristine steep-sided valleys.

Hundreds of sandstone caves and rock shelters harbour the largest concentration of early rock art in sub-Saharan Africa.

The wider landscape (adjoining the world heritage site) suffers from widespread soil erosion, and significant problems of invasive exotic vegetation.
uKhahlamba-Drakensberg - South Africa
The potential for proclaiming a
Wild Coast Geopark

Vindina Mitha,
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The Natural Heritage
Characteristics of Wild Coast Area

- Cenozoic raised shoreline deposits & dunes
- African landsurface remnants
- Late Cretaceous shoreline deposits (Mboyti & Mngazana Formations)
- Gondwana breakup half grabens
- Dolerite sills and “Gap Dykes”
- Ecca Group
- Dwyka Group
- Msikaba Formation (Cape Supergroup)
- Beattie Anomaly
- Oldest units in the Natal Metamorphic Province (Sikombe granite)
Waterfall Bluff shoreline: one of only eight places on earth where rivers flow directly over waterfalls into the sea.

Fluvial Incision: The Collywobbles

Pleistocene palaeoshorelines and coastal terraces
‘Gap dykes’ are trench-like erosion features where dolerite dykes have rapidly weathered and eroded away much like a cookie cutter along the gap outlines.
Mzizangwa River Gap dyke at Magwa Falls

Vertical valley sides & straight river gorges
Rich Cultural Heritage: the Stone Age, Iron Age farmers, San & Strandlopers

- Occupation by Late Stone Age (San) people along coastal margins or farther inland
- Painted rock shelters present at Mkambati & other places along the Wild Coast
- Shell middens & artefacts
- Mkambati Valley rock shelter ~500m from the coast: cave floor littered with shells & isolated artifacts
Cultural Heritage: Shipwrecks

Photo credits: Clive and Edith Dennison
South Africa has a rich geological history which spans over 3.6 billion years with the oldest rocks found in the Kaapvaal Craton to a succession of ancient basins such as the Witwatersrand Basin, to meteorite impact of the Vredefort dome to the intrusion of one of the largest igneous complexes in the world (Bushveld Complex), and to the more recent Karoo Basin and the Drakensberg volcanics.

We have many potential geosites and geoheritage sites within the country that can be of interest in a geopark context. Yet very few geological sites are protected / conserved and known to the public.

Many of the world-class geoheritage sites in this country suffer from neglect due to a lack of funding or concern. Subsequently it is poorly marketed and sometimes inaccessible.

What we have: - expert local knowledge on many geoheritage sites and the drive to make this knowledge available.

What we lack: - A national body to promote the geoheritage sites and unification as a geoheritage community.
Actions Needed for Establishing SA Geoparks

- The process of joining the GGN can be challenging. Various affected and interested parties must be brought on board the process.
- We need sufficient support from national & local government agencies, NGO’s, tourism & cultural heritage organisations for the establishment of the Geoparks. A Govt agency to take responsibility to protect the geosites.
- Identify potential geological sites that are scientifically and or culturally significant (in a Province or nationally and / or internationally).
- Necessary funding needs to be secured for the needed studies on geosites for the preparation of the Application Dossier for submission to UNESCO, and for the management & protection of the potential geosites.
- Work together & form task team with interested parties to approach Dept of Tourism (DoT) with proposals and strategies for Geotourism initiatives (Geoheritage Sites, Geotrails and finally Geoparks from Potential Sites).
- Maintain relationship with local stakeholders and integrate with the broader Geotourism community both locally and internationally.
- Produce a web-based, integrative geoheritage presence (online interactive map of geosites) for informing the public.
The African Geoparks Network “AGN” was created by the African Association of Women in Geosciences “AAWG, www.aawg.org” during the pre-congress of its fifth conference held in Abidjan, Ivory Coast in May 2009. The AGN aims to identify, promote, and advise on the importance and preservation of geological sites in Africa in collaboration with other stakeholders.

This initiative has got the support of IUGS, GSAf and many other national organizations. In that Framework, the AAWG and the AGN in collaboration with UNESCO Cairo Office organized the First International Conference on African and Arabian Geoparks which was held in El Jadida (Morocco), 20-28 Nov 2011.

The AGN has created a common task group in order to promote the African geology and called all geoscientists who are working on the African continent to send nice photos of geological sites of scientific and/or educative interest or just with a scenic beauty with a short description that will be published on the AGN website as well as on its related Facebook page.

AGN is organising the 2nd International Conference of Geoparks in Africa & Middle East “ICGAME2” (entitled Geoheritage for local socio-economic sustainable development) to be held in Dakar, Senegal, 1-4 October 2014.
Rössing Dome (Namibia) with open pit uranium mine – one of the world’s largest

Spitskop – Iconic Damara granite peak - Namibia
Fish river canyon incising Nama sediments – Southern Namibia

Oldonya Lengai carbonatite volcano – Rift valley N Tanzania
International Geoscience Programme

- The UNESCO is working with the International Union of Geological Sciences (IUGS) to mobilize global cooperation in the Earth sciences through the International Geoscience Programme.

- This Programme has provided a platform for scientists from across the world to push the frontiers of knowledge forward through concrete projects.

- In 2011, the Programme supported work on five themes:
  1. Earth Resources: Sustaining our Society
  2. Global Change: Evidence from the geological record
  3. Geohazards: Mitigating the risks
  4. Hydrogeology: Geoscience of the water cycle
  5. Geodynamic: Control our environment

- The Programme has always built bridges between disciplines and between scientists, including young ones, with aims of stimulating cutting-edge research and sharing scientific knowledge for the benefit of all.
In involvements of CGS in International Geoscience Programme

IGCP 601 - Seismotectonics and seismic hazards in Africa

- The African continent includes seismically active zones with significant late Pleistocene and Holocene tectonics (last 100 ka) that characterize the continental deformation and its permanent background seismicity.

- The realistic assessment at a regional scale of geological and geophysical hazards requires the building of a databank.

- The seismic hazards being among the major threats of the continent, seismotectonic studies and maps are a necessary step for the mitigation of earthquake disasters in Africa.

- In this project, the preparation of thematic maps in earthquake hazards constitutes an important objective necessary for the social and economic development of Africa.
Seismotectonics & Seismic Hazards in Africa

This project supports the UNESCO IGCP Theme “Geohazards: Mitigating the risks”

http://eost.u-strasbg.fr/igcp601/

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« Seismotectonics & Seismic Hazards in Africa »

OBJECTIVES

- Buildup of a database for the Seismotectonic Map of Africa
- Regional seismotectonic models
- Implement studies on earthquake and tsunami hazards
- Direct cooperation between African research and training centres

The work involves preparation of a map from a synthesis of 6 seismotectonic provinces from compilation of several catalogues and study of individual events
Seismotectonic Analysis

- How faults generate earthquakes (distribution, kinematic & strain rate)
- Crustal structures, seismogenic layer and strain rate
- Elastic rebound and the ‘seismic cycle’
  - preseismic movements
  - co-seismic rupture
  - afterslip and postseismic relaxation
- Interseismic loading, stress and strain build up
  - preseismic deformation, paleoseismology
- Develop mechanical models of fault behaviour
- Develop regional seismotectonic models
- Seismic zoning for Seismic Hazard Assessment
Field observations

El Asnam earthquake (10/10/1980, Mw 7.3)

Zemmouri earthquake near Algiers
23/05/2003, Mw 6.8
IGCP – 601 Perspectives

- Improving the database of seismicity, neotectonic, and crustal structure
- Developing the seismotectonic database in regional gaps
- Regional analysis of the seismically active zones in Africa
- Improving the GIS interface of geologic and geophysical database
- Seismic hazard assessment (Map ?)
- Risk analysis, prevention and warning systems
IGCP - 601
SEISMOTECTONIC MAP OF AFRICA

This map is prepared in the frame of the IGCP - 601 Project "Seismotectonics & Seismic Hazards of Africa" by the following working group:

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Future actions

- IGCP Project-601 ends in 2014
  Final map version

- Joint IGCP-601  - Africa-Array meeting in Algiers (Seismic hazard assessment, 2015)

- IGC 35 in South Africa in 2016 – Map edition with CGMW
IGCP 624 - OneGeology
• OneGeology is an international voluntary initiative of the geological surveys of the world. This ground-breaking project was launched in 2007 supported by a number of global and regional bodies, in particular the Commission for the Geological Map of the World (CGMW).
• OneGeology's aim is to create dynamic digital geological map data for the world.
• The Objectives of OneGeology are:
  – To be the provider of geoscience data globally;
  – To ensure an exchange know-how and skills so all can participate;
  – Use of the global profile of OneGeology to increase awareness of the geosciences and their relevance.
• CGS provided the geological map data (1:1,000,000), SADC map as well as the 1:1M Mozambique geological map (available on the OneGeology Portal).
Maps in the OneGeology Portal

National geological map data is globally accessible through a single portal.
SA Geology in OneGeology Portal

http://portal.onegeology.org/
Involvement in Antarctic Research Project (JARE 51)

• NRF funded geological research is focusing on aspects of the evolution of the supercontinent Gondwana through the correlation of rock units between southern Africa and western Dronning Maud Land, Antarctica as well as the geological evolution of the two areas, recognising their juxtaposition prior to the breakup of the Supercontinent of Gondwana ~180 Ma ago.

• Antarctic Research forms part of Global Change Grand Challenge component of DST’s ten year plan for 2008-2018. *It can also form as an input for the UNESCO’s IGCP Theme “Global Change: Evidence from the geological record”*. 

• The research contributes to the fulfilment of South Africa’s obligations to the Antarctic Treaty System of which South Africa is a signatory and also contributes to the research aims of SCAR, (Scientific Council for Antarctic Research), an affiliate of the International Union of Geoscience (IUGS) and ICSU, the International Council of Scientific Unions.

• International collaboration in the project has involved researchers from Mozambique, Japan and Norway with local collaboration including personnel from the Universities of Cape Town, Pretoria and Johannesburg.
Diagram showing a reconstruction of Gondwana and the areas of study under JARE 51

Activities performed:
Field mapping, sampling and research aimed at understanding the tectonic evolution involving geochemistry, geochronology and metamorphic P-T work.
Collaborative research: Global change in deep time (Permo-Triassic boundary, Karoo Basin)

- The Beaufort Group (Karoo Basin) preserve a record of life over a period of 25 ma.
- It records environmental changes and adaptations, including ecosystem response to the catastrophic end-Permian mass extinction (~251 ma).
This project utilizes a variety of data sets and skills provided by researchers from a number of research institutions.

**Plant fossils, Insect-plant interaction & fossil pollen:**
- Albany Museum
- University of California, Berkeley

**Sedimentology & Geochemistry:**
- Colby College
- CGS

**Radiometric dating:** University of Toronto

**Paleomagnetic Research:**
- University of Texas, Dallas

**Fossil wood:** Wits University

An input for the UNESCO’s IGCP Theme “Global Change: Evidence from the geological record”
• These datasets are integrated to:
  – Improve our understanding on how pre- and post extinction ecosystems differ; and
  – Better understand how ecosystem responded to the impact of an as yet undetermined external stressor.

• Early results show that current models are too simplistic
• But the work continues.
These products may be used as inputs to support the UNESCO IGCP Theme “Earth Resources: Sustaining our Society”
Thank You