NWU®

Inaugural address

by

Prof Manny Mathuthu

19 July 2018

17:30 for 18H00

Faculty of Natural and Agricultural Sciences

THE ROLE OF NUCLEAR SCIENCE IN NATIONAL SECURITY
(Nuclear does NOT mean Bomb!)

INAUGURAL LECTURE

By

Prof Manny Mathuthu

19 JULY 2018

Centre for Applied Radiation Science and Technology (CARST)

Manny.Mathuthu@nwu.ac.za

ABATRACT

Nuclear Security has become a National concern worldwide since the Bombing of the USA Twin Towers in 2011. The aim of this presentation is to provide public assurance that nuclear science is not about making nuclear bombs. In this lecture we present the Main Threats to National Security, mitigative measures that each Government (of South Africa) needs to take and the Role of Nuclear forensics in National security, and the research outputs on this emerging Focus Area. We will describe also the Mandate of the Centre for Applied Radiation Science and Technology (CARST) in National security.

Three Function of this Inaugural Lecture are to describe:

- My Profile
- Capacity building at CARST and
- NWU Marketing strategy for the Centre

Three Function of this Inaugural Lecture

(A) My Profile

- Expertise in Nuclear Science
- Contribution to Nuclear Science
- NWU Mission and my Role therein

(B) Capacity Building

- Teaching &Training
- Research & Development
- Infrastructure & Personnel

(C) NWU Marketing

- Conferences & Publications

(A) My Profile

Position

Full Professor at the Centre for Applied Radiation Science and Technology (CARST)

Qualification

- PhD in Nuclear and Plasma Physics (University of Zimbabwe, 1998)

Expertise and Contribution

- Applied Radiation Science
- Nuclear Forensics
- Nuclear technology application
- Training

(B) Capacity Building

- Teaching &Training
- Research & Development
- Infrastructure & Personnel

(C) NWU Marketing

- Conferences & Publications

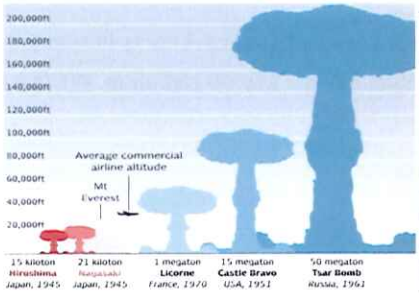
WHAT IS THE PROBLEM??

- Public Fear of Nuclear Radiation
- Lack of Security and Safety
- Nuclear Activism
- South Africa is No 2 in World Carbon Pollution
- Lack of Public Education on Advantages of Nuclear Technology

Nuclear Incidents

- HIROSHIMA 08/1945
- CHENOBYL 1986
- FUKUSHIMA 03/2011
- TWIN TOWERS 9/2011
- FRANCE 2015
- RADIOLOGICAL EXPOSURE

The above examples show nuclear accidents and events over a 68 years. Notice that more events are occurring over shorter time intervals these days. And these are acts of sabotage.



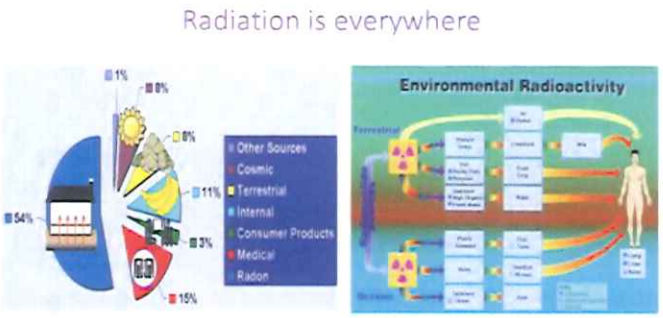
Comparison to Hiroshima

Nuclear detonation (Tsar Bomb-Russia)

Fukushima nuclear accident

Twin Tower attack (Plane crash)

Radiation is everywhere



Nature has radiation as part of our Living exposure. This is illustrated in the above Figure. We live with radiation. We live on radiation. We live by radiation.

WHAT IS NATIONAL SECURITY??

1. ***NATIOANL PEACE AND SECURITY***
2. ***SAFEGUARDING NATIONAL RESOURCES***
3. ***SAFETY OF CITIZENS***

RADIATION SYMBOL

The IAEA has two radiation symbols. They enable us to know a radioactive source in a container and thus avoid exposure by maximizing our distance and time

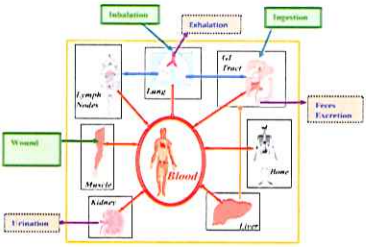
Trefoil Ionizing radiation (LHS) and NEW Standard ionizing radiation warning (RHS)

National Resources:

They include uranium and gold deposits underground.

Only Uranium (U) is discussed hence forth.

The Uranium Yellow cake (ADU)



Hazards of uranium intakes

Safety of Citizens

Entails informing the public about the dangers of radiation exposure, the regulatory requirements for Radiation Facilities (X-RAY, CT SCAN, NPP etc)

What are Threats to National Security??

- ***WAR***
- ***CIVIL UNREST***
- ***NUCLEAR SUBOTAGE;***
- ME OR YOU TODAY;
  Let's Estimate the Damage; ***http://nuclearsecrecy.com/nukemap/***

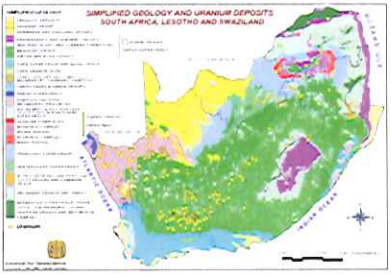
Research & Development

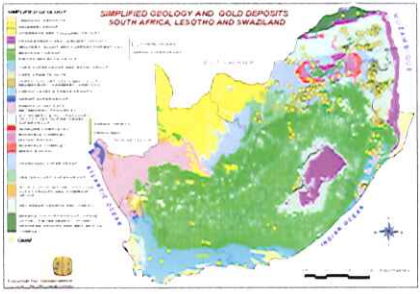
- Uranium deposits; http://www.geoscience.org.za/images/Maps/uranium.gif
- Gold deposits
- Uranium Provinces of South Africa
  - Karoo Super group
  - Namaqualand
  - Springbok Flat Basin
  - Witwatersrand Super group

National Provinces of South Africa

South Africa has 9 National Provinces each endowed with Resources that need to be safeguarded.

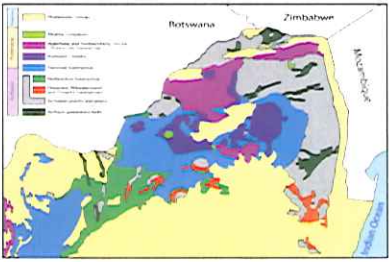
Then the Country has uranium and Gold deposits which are closely associated together in mining activities.



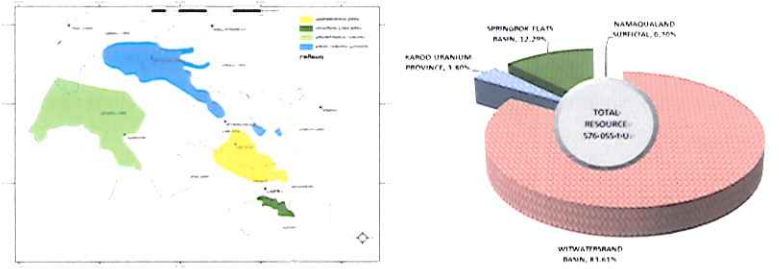


However the first Uranium deposits in the world are found in the Dominion Reef and Witwatersrand Supergroup in South Africa. These deposits have been estimated by Khumalo and Mathuthu to be around 4.350 Ga old [1].

This is one Resource that South Africa must gurad against its Proliferation for illicit purposes.



Dominion/Witwatersrand Uranium Deposits [2]



Uranium Provinces in South Africa (LHS) & Their proportions (RHS) [3]

ROLE OF NUCLEAR FORENSICS

1. Aim and Objectives
2. Nuclear Forensic Signatures
3. Uranium Ore Dating (Pb-Isotopic)
4. Bomb Origin (Investigation, Attribution)
5. Law Enforcement
6. National Signatures
7. National Nuclear Forensic Library (NFL)

Aim of U-Pb Isotopic Ratio Technique

To Determine Lead isotope ratios for Nuclear Forensic signatures for South African Uranium Mining and Processing.

Objectives are to:

- Resolve the U, Pb isotopic ratio for nuclear forensics signatures for the mine
- Develop a nuclear forensics Library for U & Pb from the mine
- Use Library to trace origin of interdicted nuclear material

Introduction to Nuclear Forensic Signatures

In South Africa there is a vast uranium ore (uraninite) deposits (Fuchs, Williams-Jones et al. 2016), with a lot of mining and processing activities. It is therefore imperative for South Africa to properly collect and compile databases and national libraries for nuclear forensic signatures. These can be used as evidence for attribution of the seized nuclear or radioactive material. The Carletonville Gold field) in South Africa has been investigated by Researchers like Mathuthu and Ntokozo (2017) ; Fuchs et. al. (2016). He used a ICP MS and LA-ICP-MS respectively to measure trace elements (provenance of uranium) on the Transvaal Supergroup. Results showed that the higher U and gold concentrations are embedded in the pyrite rock (Fuchs, Williams-Jones et al. 2016).

Limitation of this work

Only Results from the *front end in the fuel cycle* are described, the data presented could form a basis for a South African nuclear forensics library. However, all the stages in the fuel cycle need to be investigated to produce a comprehensive nuclear

forensic library. Here we describe the investigation of Pb isotopic composition and trace elemental analysis to determine respectively the fingerprint lead signatures and the provenance of the uranium in the uraninite ore. Interpretation of the results for possible tracing (attribution) of the origins of South African U is presented. We also discuss limitations of Pb isotopic fingerprinting technique in this work (Cheng and Hu 2010).

Materials and Methods

Isotopic Techniques; Many Instruments are being used to apply various analytical techniques for chronometric analysis of intercepted nuclear materials from a nuclear facility. For example (Andersen 2002, Balcaen, Moens et al. 2010, Varga, Katona et al. 2010):

- The laser ablation (LA ICP-MS) instruments and the
- The laser-ablation micro-sampling (LAM-ICP- MS)
- Perkin Elmer NexION 300Q ICP-MS Isotopic ratio analysis

have been used for determining the lead isotopic signatures of the sample material

Study area

The Witwatersrand and Dominion Area shown below was used for sampling points

Witwatersrand and Dominion Study Area (LHS) & Sampling pattern (RHS)

Geology of the mining site

The sampling site falls within the Carletonville goldfields which is part of the so called B-Reef or Witwatersrand Super group of South Africa. The uraninite (UO_{2x}) [4] and quartz-pebble conglomerate-hosted [3] deposits here are unconformity in nature lying on the sedimentary succession of the Witwatersrand super group, with an estimated age of about 2.59 Ga [5]. Gold (and uranium) mining here uses the underground mining techniques as the mines are each estimated to be more than 2 km deep with uranium deposits that are the oldest in the world, just about 4.350 Ga years [6]. These mines are now over 132 years old, [7] and are still operational.

Problem with Uranium Nuclear Material

The seizure of illicit trafficking of nuclear material has spread to non-nuclear weapons states since the break-up of Soviet Union during 1990's. Consequently, these non-States have adequate nuclear material to make up improvised nuclear devices. One of the strategies to combat illicit trafficking of nuclear material is by the identification and characterization of nuclear material by each country. It is thus imperative for CARST laboratory to develop rapid analytical methodologies that can resolve the signatures of nuclear materials within hours of interdiction or recovery [8, 9]. These signatures are then compiled and stored in a nuclear forensic library [10]. A national nuclear forensic library for South Africa will enable the country to identify nuclear or radioactive material produced within its own boarders, thereby keeping these materials under regulatory control [11].

Equipment used

High Purity Germanium Detector (HPGe) (LHS) and NexION 2000Q ICP-MS (Perkin Elmer) (RHS)

(Canberra HPGe Well detector)

RESULTS

Lead isotopic ratios for water samples after $^{208}Pb/^{206}Pb$ normalization for mass balance.

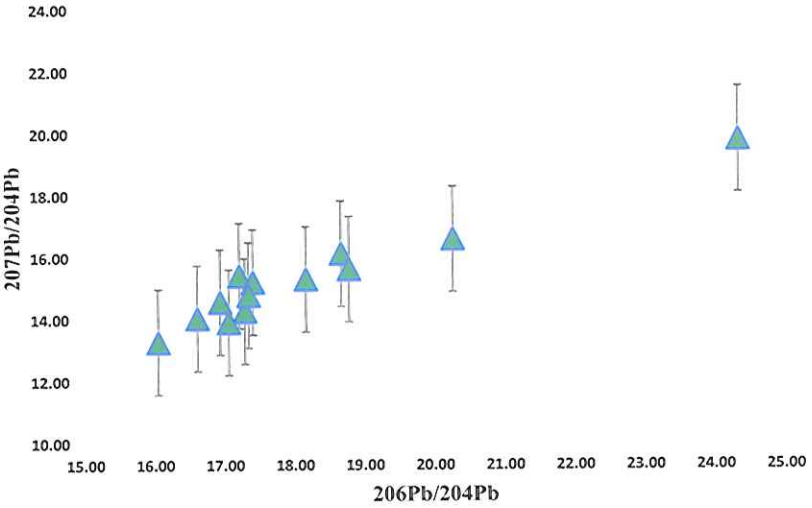
Sample ID	$^{208}Pb/^{206}Pb$ -normalized	$^{208}Pb/^{206}Pb$ normalized	$^{204}Pb/^{206}Pb$ normalized
	$^{207}Pb/^{206}Pb$	$^{208}Pb/^{206}Pb$	$^{204}Pb/^{206}Pb$
CW4	0.8254 ± 0.0640	1.987 ± 0.0873	0.0578 ± 0.0037
WV14	0.8738 ± 0.0734	2.0187 ± 0.0978	0.0574 ± 0.0025
DAM31/3	0.8154 ± 0.0673	1.9487 ± 0.0732	0.0586 ± 0.0037
WV13	0.8271 ± 0.0782	2.0426 ± 0.0895	0.0623 ± 0.0047
DSW9/14	0.8128 ± 0.0687	1.8810 ± 0.0852	0.0411 ± 0.0023
DSW21/11	0.8187 ± 0.0675	1.9329 ± 0.0789	0.0493 ± 0.0038
DSW199	0.8454 ± 0.0674	2.0693 ± 0.0796	0.0602 ± 0.0046
DSW7/12	0.8958 ± 0.0596	2.0564 ± 0.0864	0.0581 ± 0.0039
DSW43/19	0.8638 ± 0.0769	2.0558 ± 0.0897	0.0536 ± 0.0047
DSW39/17	0.8320 ± 0.0694	2.0753 ± 0.0786	0.0532 ± 0.0037
DSW18/3	0.8528 ± 0.0654	2.0837 ± 0.0698	0.0577 ± 0.0051
DSW4/5	0.8601 ± 0.0684	2.0678 ± 0.0944	0.0590 ± 0.0034
AVER	0.8436 ± 0.0598	2.0183 ± 0.0897	0.0557 ± 0.0051
SDEV	0.0261	0.0660	0.0058
%RSD	3.0962	3.2722	10.3423
NIST SRM 981	0.91464 ± 0.00033	2.1681 ± 0.0008	0.059042 ± 0.000037

National Nuclear Forensic Library (NFL)

Hererlook at

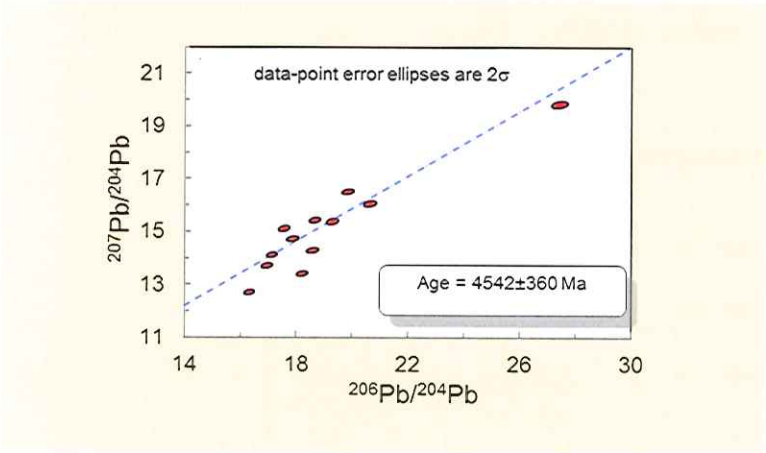
- Lead (Pb) Isotopic Ratios
- Rare Earth Elements Patterns
- Uranium Ore dating

Pb-Pb isotope geochemistry



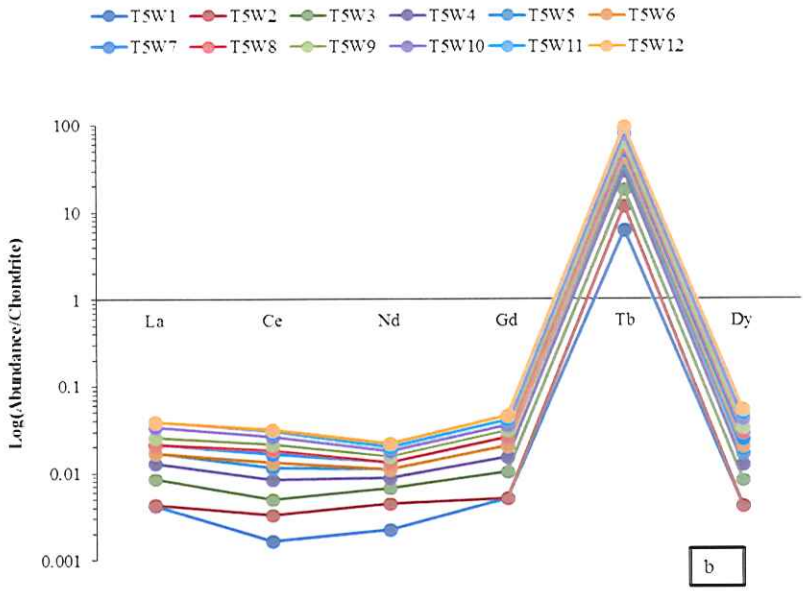
Uranium Ore Dating (Pb-Isotopic)

We used the **Isoplot Code** to evaluate the Age of the 3 km deep uranium deposit. It is calculated to be 4.542 Ga ± 0.360 Ga as shown below. This is in agreement with Cuney's Earth's Clock History diagram [2]



Lanthanides (Ree) Signatures

- REE Patterns show different signatures from each Uranium deposit
- Fractionation of the Uranium series can be used to identify change of Geological conditions e.g.. Hydromelting
- In figure below we see that the Witwatersrand Gold/Uranium deposits are characterized by a Terbium (Tb) anomaly which gives a signature for the target mine deposit.



Discussions on ICP-MS Results

- The results from Table show that all the DWS water samples from this mine have lead isotopic ratios close to the NIST SRM 981 values.
- The uranium ore mineralisation is a pyrite, with Pb ratios similar to that found by Jopoul et al. (Poujol 1999).
- The isotopic signatures are less radiogenic ($^{206}Pb/^{204}Pb \leq 20$).
- Also the Pb-Pb plot for these results , confirm that the Carletonville gold fields are pyrite deposits, giving another signature for this mine of the Dominion Age (3.08 – 4.60 Ga)

ROLE OF CARST IN NUCLEAR SECURITY

- Capacity building for nuclear industry
- Training of Nuclear forensic Scientist and Gvt officers on radiation detection
- National lab for nuclear forensics signature

Research and development (analysis labs)

Applications of Nuclear Technology

- In Agriculture
- Industry
- Medicine
- Research (NWU – CARST)

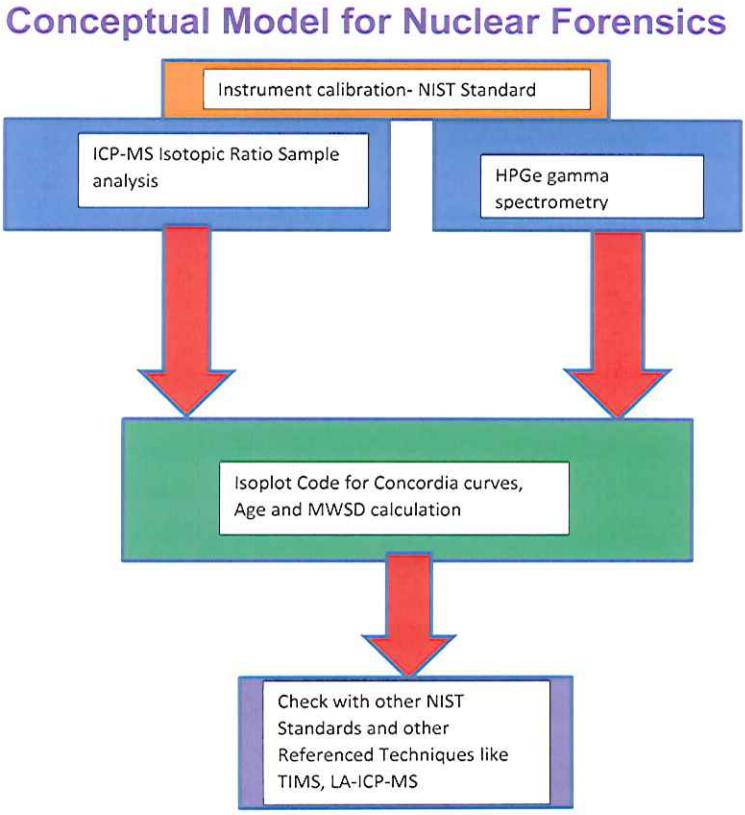


Figure 29: Proposed Nuclear Forensics Protocol for CARST.

CONCLUSIONS: NUCLEAR IS *"KOOL"*

- NUCLEAR RADIATION IS IN NATURE
- DANGEROUS IN WRONG HANDS
- VALUBLE IN EDUCATED MINDS
- URANIUM PROVINCES ARE RESOURCES OF NUCLEAR POWER FOR SOUTH AFRICA
- MITIGATION AGIANST CARBON PRINT (POLUTION)
- NUCLEAR FORENSICS SAFEGAURDS OUR U PROVINCES
  - WE CAN IDENTIFY OUR URANIUM BY ITS AGE, PB GEOCHEMISTRY AND REE PATTERNS
  - Don't fear Nuclear, Fear God!!
- NUCLEAR IS *KOOL*!!

RESEARCH OUTPUTS (2012 – 2017)

- ***Publications (25 peer reviewed articles)***
- ***Conferences (IAEA URAM 2018, NICSTAR 2018 etc.)***
- ***MSc & PhD Graduates (2 PhD & 7 MSc Grandaunts)***

CARST GRADUATES PHOTO GALLERY (2016/7)

Left to Right: Dr Nhlakanipho, (hidden), Dr Kamunda, Dr Cyrus, Prof Mathuthu, etc

ACKNOWLEDGEMETS

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- **International Atomic Energy Agency (IAEA), in Austria, for sponsoring this Project under CRP J2003, Grant No SAF577**
- **National Research Foundation (NRF) for supporting the Nuclear Forensics Project at CARST, NRF Grant No IBPU180305315870**
- **My Wife ANNA and Family for their Un-Wavering support.**

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