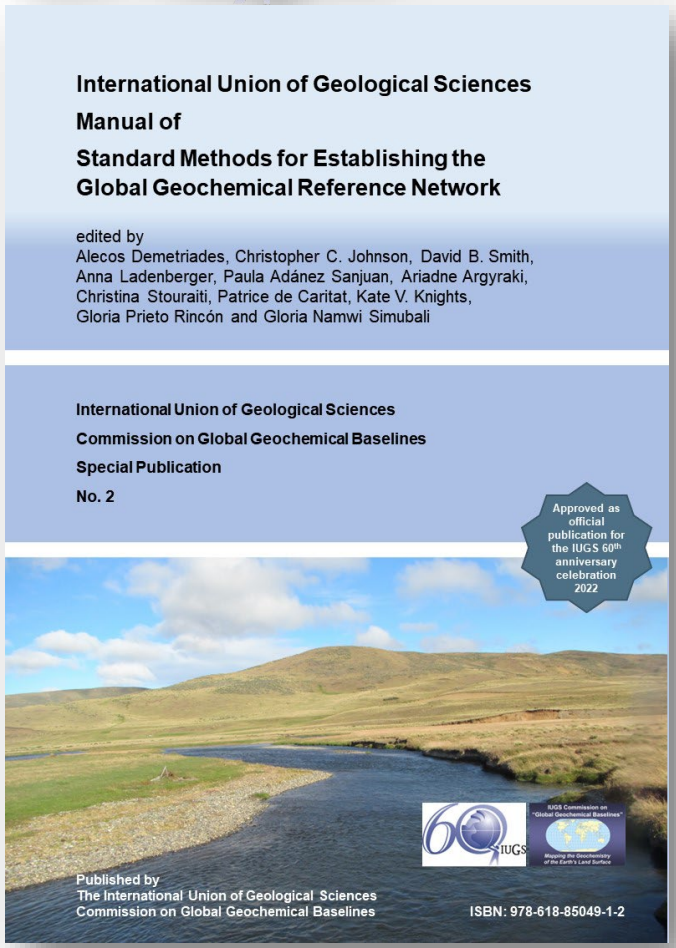


International Union of Geological Sciences Manual of Standard Methods for Establishing the Global Geochemical Reference Network

***Alecos Demetriades**, Christopher C. Johnson, David B. Smith, Anna Ladenberger, Paula Adánez Sanjuan, Ariadne Argyraki, Christina Stouraiti, Patrice de Caritat, Kate V. Knights, Gloria Prieto Rincón and Gloria Namwi Simubali*

IUGS Commission on Global Geochemical Baselines

July, 1962: Start of my journey at the age of 15.

My home country:
Cyprus – birth place of Aphrodite

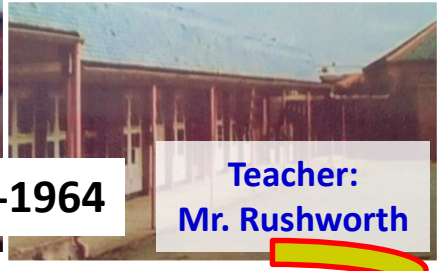
Larnaka

My education country:
United Kingdom

Coventry

Barker's Butts Secondary School for Boys

1962-1964



Teacher: Mr. Rushworth

1964-1966

Lecturers: Mr. Edwards & Mr. Alec Chater

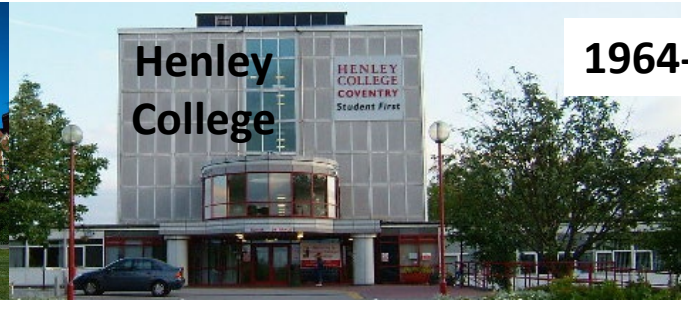
Coventry Technical College

1968-1970

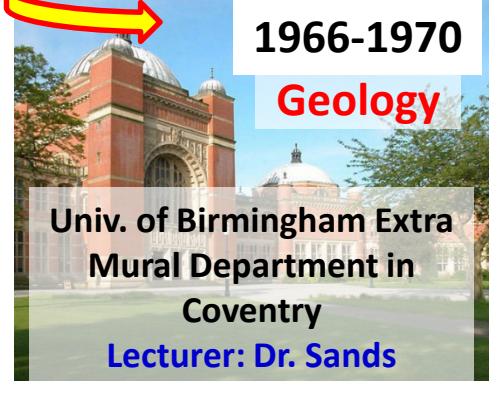
1966-1967 **Geology**

Bablake Grammar School

Henley College



1966-1970 **Geology**



Univ. of Birmingham Extra Mural Department in Coventry
Lecturer: Dr. Sands

1967-1968 **+Geology**

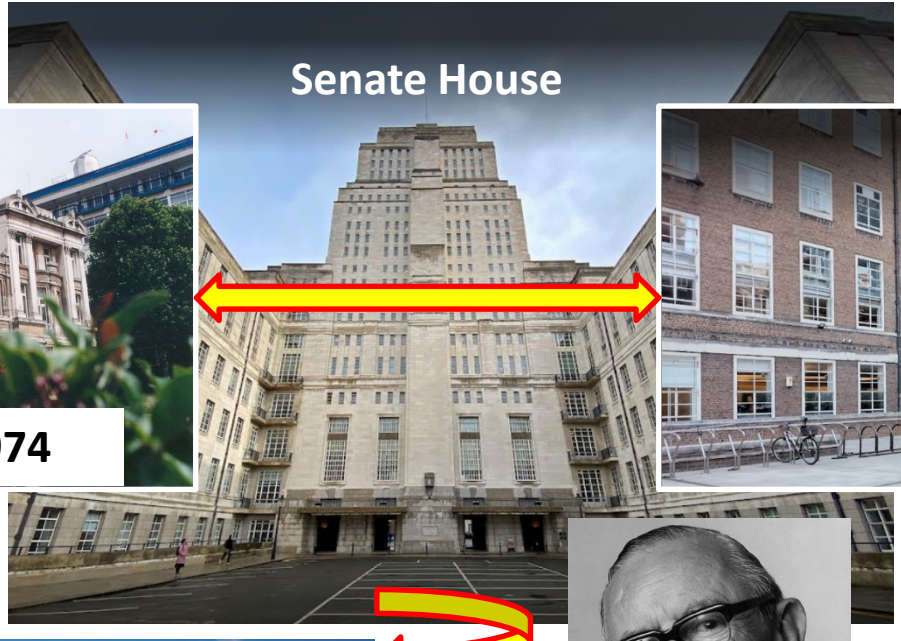
Nuneaton Technical College & School of Art

University of London (1970-1974)

Queen Mary College

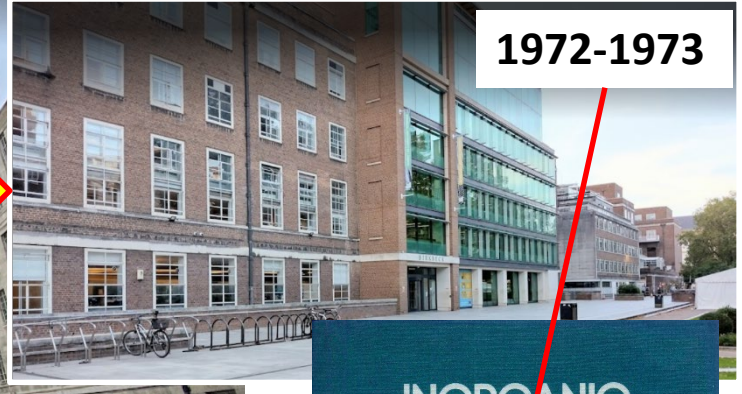
B.Sc.(Hons) Geology

1970-1972 & 1973-1974



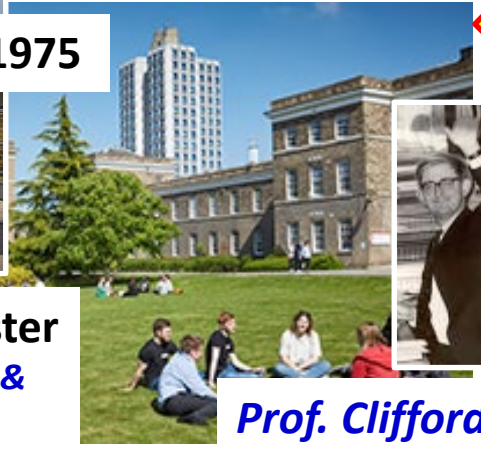
Birkbeck College

(Geochemistry, Geophysics, Photogeology)



1972-1973

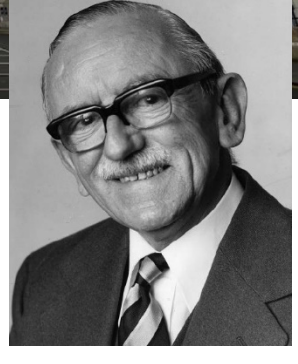
1974-1975



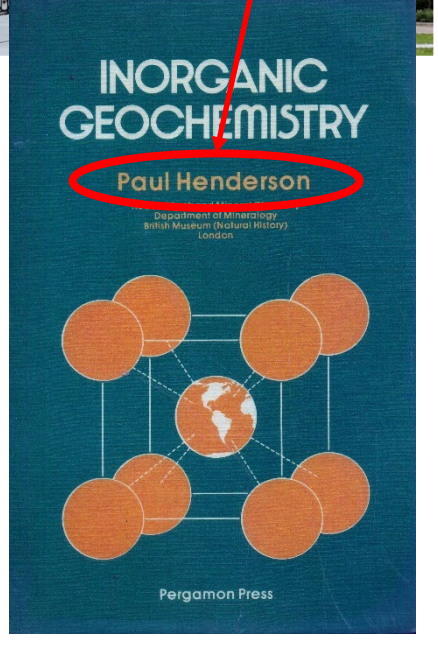
University of Leicester

M.Sc. Mining Geology & Mineral Exploration

Prof. Clifford H. James



1974: Prof. John S. Webb
Father of "British Applied Geochemistry"



Finally, during my retirement at the age of 70 completed my Ph.D. in Applied Geochemistry (2017) at the

University of Patras
School of Natural Sciences
Department of Geology

Professor Sotiris Varnavas

Why did I do my Ph.D. at such a late age?

As a professional applied geochemist, and not interested to follow an academic career, I was totally devoted to my work at the Hellenic Geological Survey. Hence, I was interested in professional titles and followed the Continual Professional Development (CPD) programme of the Geological Society of London, the European Federation of Geologists and the Institute of Materials, Minerals & Mining for the professional titles of:

- Chartered Geologist (C.Geol.),
- Chartered Scientist (C.Sci.),
- European Geologist (EurGeol), and
- Chartered Engineer (C.Eng.).

As I was registered for the Ph.D. title from 2002, the doctorate thesis was completed out of respect to Professor Sotiris Varnavas before his retirement.

Worked at Rio Tinto Finance and Exploration Ltd. (RioFinEx) as a Researcher in the development of a Global Mineral Deposit Inventory 1972-1973 & Summer months of 1974.

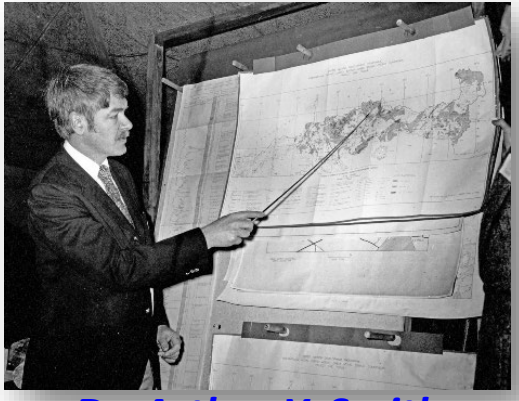
Mr. Keith R. Greenleaves

Worked at the Hellenic Institute of Geology and Mineral Exploration (I.G.M.E.) as an Applied Geochemist:

- Eastern Macedonia & Thrace Regional Branch (Oct. 1976 to Sept. 1981), and
- Division of Geochemistry (Oct. 1981 to Nov. 2011 - retired) – Director of the Division from 2008 to 2011.

Since my retirement from the end of November 2011 to the present time, I devoted my time in the work of the EuroGeoSurveys Geochemistry Expert Group and the IUGS Task Group & since 2016 Commission on Global Geochemical Baselines.

During my professional career the four applied geochemists that had a great influence on me were:



Dr. Arthur Y. Smith
(Period: 1976-1978)

Dr. Ashlyn Armour-Brown
(Period: 1976-1978)

Professor Gerry G.S. Govett
(Period: 1984-1987)

Professor Bjørn Bølviken
(Period: 1986-1993)

From 1976 of my career as an Applied Geochemist until 2022, after 46 years, apart from internal I.G.M.E. project & contract reports and European Commission co-financed project reports, I have actively participated in the writing and editing of:

- 3 European Project Reports
- 3 Geochemical Atlases of Europe
- 1 Text book on Urban Geochemistry
- 6 Mapping Manuals
- 3 Quality Control reports
- 3 Special Issues of the Journal of Geochemical Exploration

And over 100 peer-reviewed papers published

SEGH members may be interested in these 3 publications:

Johnson, C.C., Demetriades, A., Locutura, J. & Ottesen, R.T. (Editors), 2011. ***Mapping the Chemical Environment of Urban Areas***. John Wiley & Sons Ltd., Chichester, U.K., 616 pp. [https://www.wiley.com/en-gb/Mapping+the+Chemical+Environment+of+Urban+Areas-p-9780470670071].

Demetriades, A. & Birke, M., 2015. ***Urban Topsoil Geochemical Mapping Manual (URGE II)***. EuroGeoSurveys, Brussels, 52 pp. **[https://doi.org/10.5281/zenodo.7319866].**

Demetriades, A. & Birke, M., 2015. ***Urban Geochemical Mapping Manual: Sampling, Sample preparation, Laboratory analysis, Quality control check, Statistical processing and Map plotting***. EuroGeoSurveys, Brussels, 162 pp. **[https://doi.org/10.5281/zenodo.7319969].**

What are the elements to achieve success in your work?

Success in your work needs the following 9 elements:

- ✓ Perseverance
- ✓ Patience
- ✓ Determination
- ✓ Self improvement
- ✓ Teamwork
- ✓ Enthusiasm
- ✓ Positive thinking
- ✓ Passion
- ✓ Balance

If one of these elements is missing, then you must think if this profession is right for you.

How to deal with your work and be successful?

"*Michael Faraday (1791-1867) may have suggested that the formula for scientific success is:*

"Work, Finish, Publish"

but Faraday said that back in the 19th century. In 2016, there are plenty of compelling reasons to tack another item onto the end of the list. Millions of scientific articles are published each year, making your work just a drop in the ocean (and we have authors who do a lot of work). In order to ensure that your work is read, cited, and has impact, it's becoming increasingly necessary to add a little self-promotion to your workflow." Hence, The Electrochemical Society is proposing to add "***Promote***" at the end of the list:

"**Work, Finish, Publish, Promote**"

How to deal with your research work and be successful?

Jules Henri Poincaré (1854-1912) was a French mathematician, theoretical physicist, engineer, and philosopher of science. He is often described as a polymath, and in mathematics as "***The Last Universalist***", since he excelled in all fields of the discipline as existed during his lifetime. His quotation is of interest to your research work as applied geochemists concerned with environmental and health related issues:

"Science is built up with facts, as a house is with stones.

But a collection of facts is no more a science than a heap of stones is a house".

I will end up this philosophical opening with another quotation by Michael Faraday:
"***Nothing is too wonderful to be true if it be consistent with the laws of nature***.
There's nothing quite as frightening as someone who knows he is right. It is right that we should stand by and act on our principles; but not right to hold them in obstinate blindness, or retain them when proved to be erroneous."

So, the only way to show your magnanimity and professionalism is to accept when you are proven wrong.

IUGS

IAEA
International Atomic Energy Agency

IUGS Commission on "Global Geochemical Baselines"
Mapping the Geochemistry of the Earth's Land Surface

1984

Initial concept of a world radiometric map

At the International Atomic Energy Agency's workshop in Sweden there was a discussion:-

- On the global mapping of the naturally occurring radioactive elements (K, U, and Th) using ground and airborne scintillometry.

It was recognised that other elements should be included.

IUGS

IUGS Commission on "Global Geochemical Baselines"

Mapping the Geochemistry of the Earth's Land Surface

What was the incident that shocked the World with a possible global disaster?

The Chernobyl accident in Ukraine, 26 April 1986, catalysed interest in global-scale geochemistry.

Source: https://www.siasat.com/ukraine-risks-repeating-chernobyl-disaster-2384806/

However,
Is it the only anthropogenic induced hazard that humanity is facing?

We are now in a New destructive era the *Anthropocene*

Humans, ever since their appearance on Earth have been modifying the natural environment in order to improve their living and working conditions.

So, we are now in a new geological era, the *Anthropocene*, characterised by humanity's extensive destructive impact on the Earth's landscapes.

According to Margaret Atwood (2015*)

"It's Not Climate Change – It's Everything Change"

*(https://medium.com/matter/it-s-not-climate-change-it-s-everything-change-8fd9aa671804)

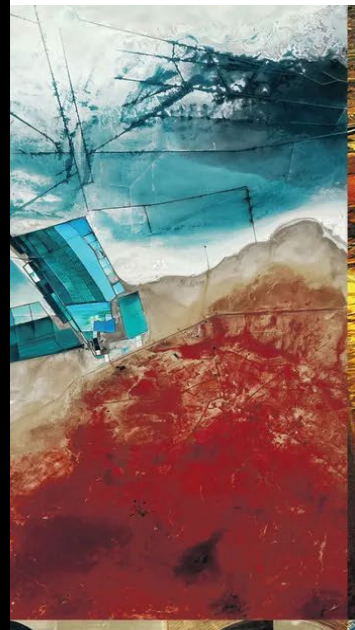
We are now in a New destructive era the *Anthropocene*

These anthropogenic induced environmental changes affect the quality of:

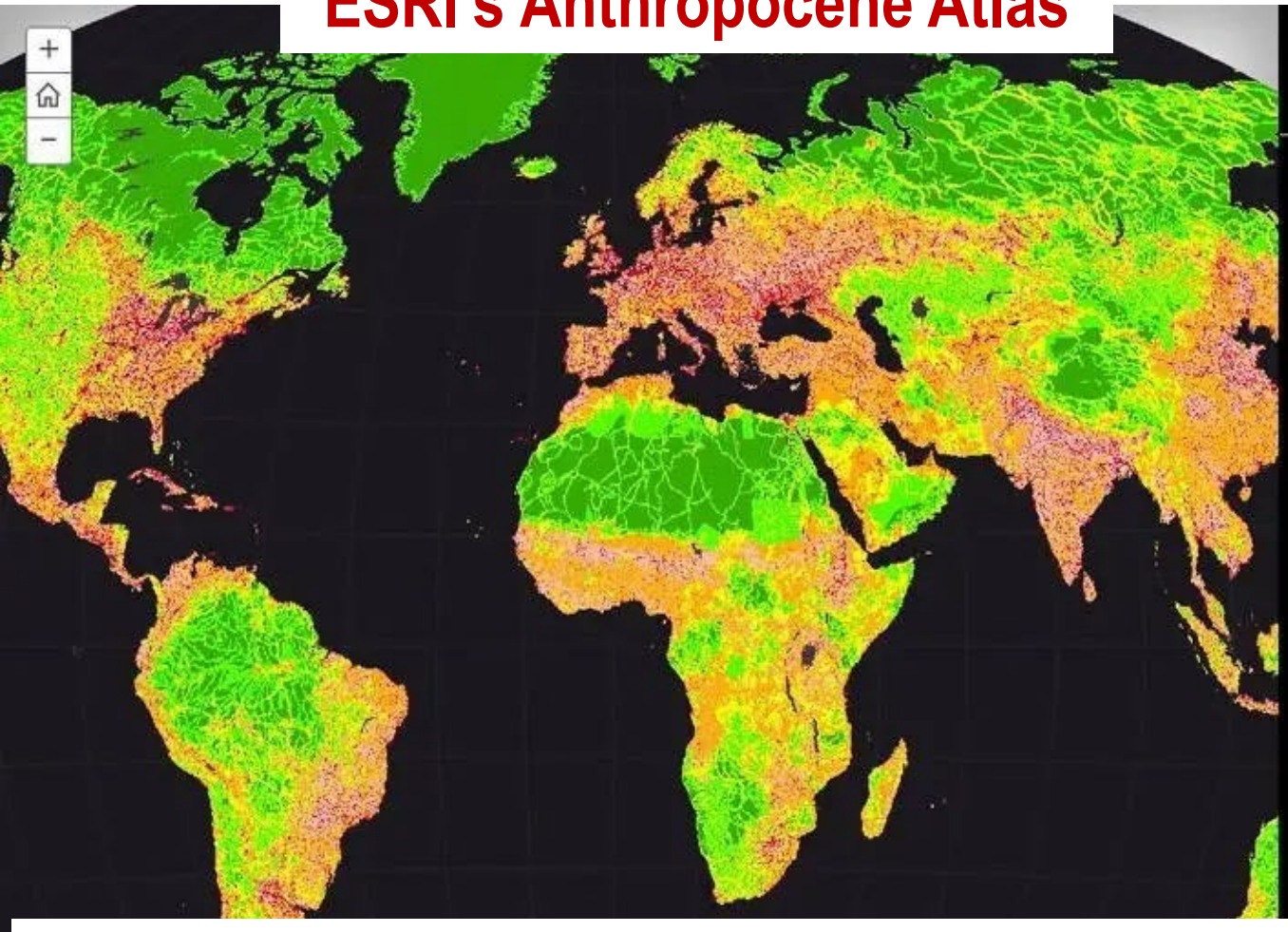
- the air we breathe (see Xiangdong Li's SEGH Fellows webinar);
- the water we drink, and
- the soil in which we grow our food.

In fact, they affect our exposure to infectious diseases, and even the habitability of the places where we live, work and play.

The **Anthropocene** defines Earth's most recent geological time period as being human-influenced, or anthropogenic, based on overwhelming global evidence that atmospheric, geological, hydrological, biospherical and other earth system processes are now altered by humans.



ESRI's Anthropocene Atlas



A story map

esri

We are Living in
The Age of Humans

75%

of Earth's land surface outside of ice sheets is managed by humans.

The map at left, developed by the Wildlife Conservation Society, reflects patterns of roads, urban concentrations, agriculture and other factors to show the extent of human modification of the landscape. Green represents minimal human impact; orange, red and purple reflect a high degree of human activity.

CLICK on the locations below to see examples of highly managed landscapes:

The Netherlands is home to this geometric array of fields and villages called the Zuiderzeewerken, an expanse of reclaimed land created by diking and draining portions of the Zuiderzee, a shallow inlet of the North Sea.

Green indicates the least modification (*e.g.*, by agriculture, deforestation, urbanisation) and **Red the most**.

Forest Landscape Integrity Index 2019 map of the Earth: Annual global index of forest condition measured by degree of anthropogenic modification

Grantham *et al*. (2020) "*Anthropogenic modification of forests means only 40% of remaining forests have high ecosystem integrity*". *Nature Communications,* **11**(1), 5978.

Central-eastern Brazil. Photograph: Copernicus Sentinel-2A/ESA

Mining operations

https://www.activesustainability.com/

Industrial operations

YOTILY/SHUTTERSTOCK

https://sogh.se/soghs-mission-on-planetary-health/

Urbanisation

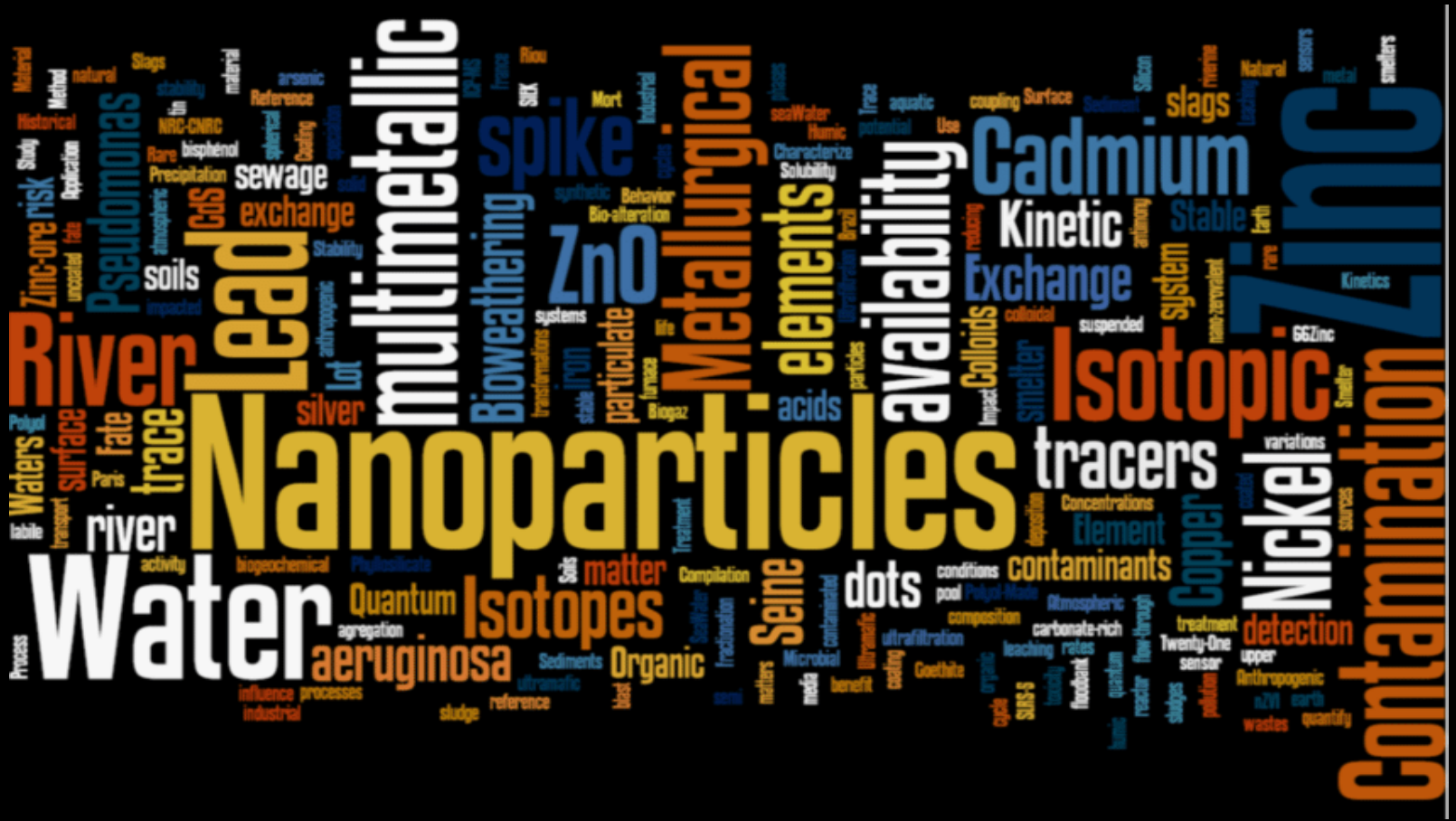
Cape Coral, Florida, home to more canals than any other city in the world. Photograph: Planet

Rubbish tips, full of long-lived materials, will far outlast humans.

(Mahmoud Zayat: AFP)

Plastics Recycling, Nairobi, Kenya. Photo © Edward Burtynsky

Anthropocene and Emerging Contaminants



https://www.researchgate.net/lab/Anthropocene-and-Emerging-Contaminants-Yann-Sivry

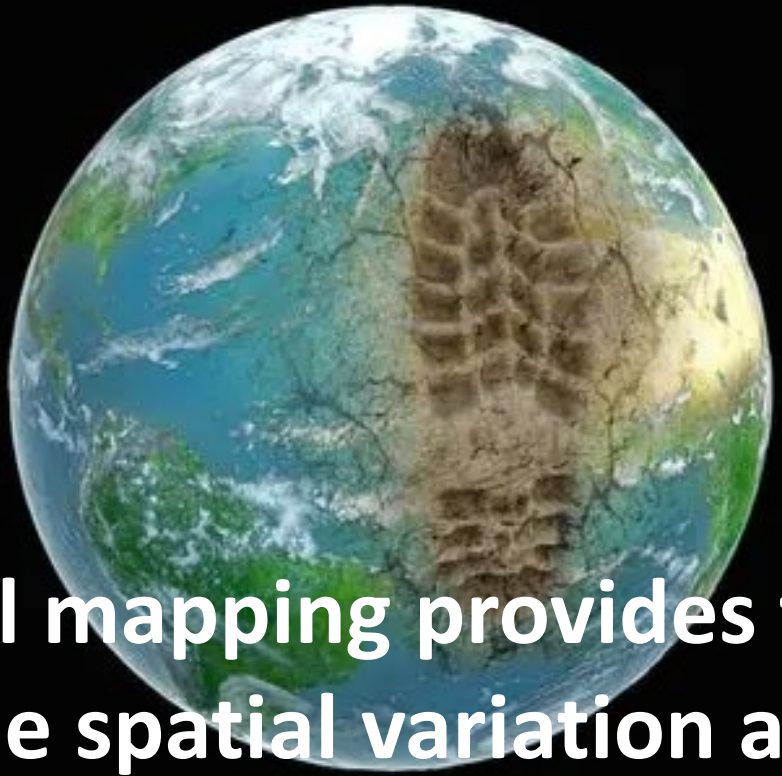
IUGS Commission on "Global Geochemical Baselines"

Soil, Sediment & Water are the most valuable natural resources for our quality of life, and we need to know their chemical composition.

Mapping the Geochemistry of the Earth's Land Surface

http://www.globalgeochemicalbaselines.eu/

SO, HOW CAN WE STUDY THE CHANGES?



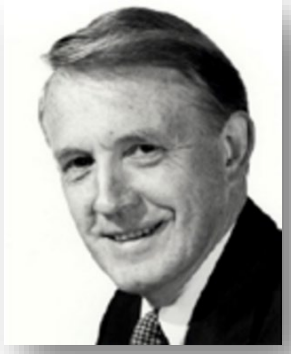
Geochemical mapping provides the tools of visualising the spatial variation and intensity of the human induced threats

https://blog.efmdglobal.org/2019/07/09/leadership-for-the-anthropocene/

The question is what sort of global geochemical baseline mapping do we need?

We do not need just any global geochemical database.

Darnley *et al.* (1995, p.x) justified the need of a harmonised global geochemical database with the following timeless statements:



Arthur G. Darnley
1930-2006
Project leader of
IGCP 259 & 360

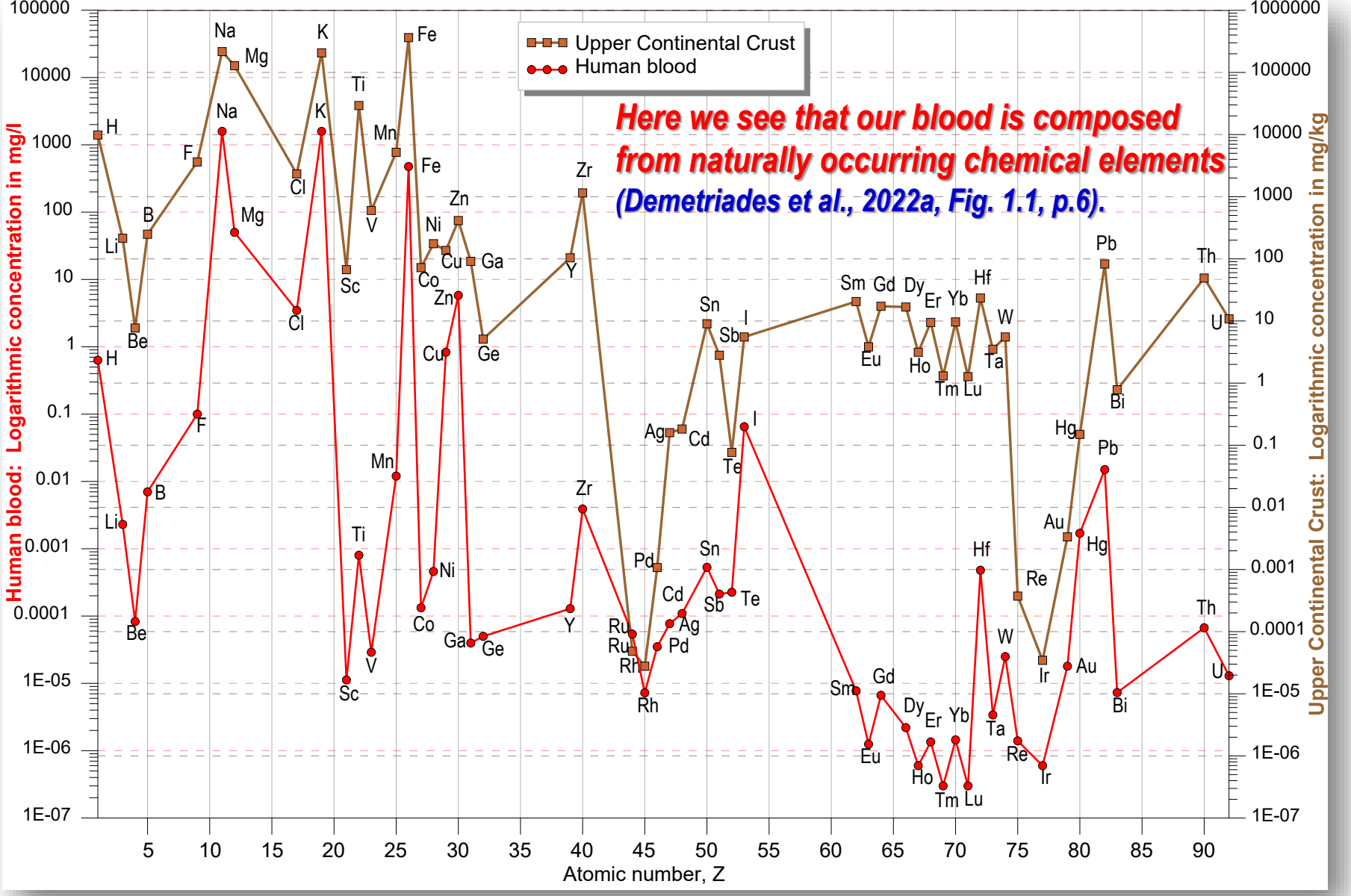
"Everything in and on the Earth - mineral, animal and vegetable - is made ….. from naturally occurring chemical elements.

The existence, quality and survival of life depends upon the availability of elements in the correct proportions and combinations" *(Darnley et al., 1995, p.x).*

IUGS Commission on
"Global Geochemical Baselines"

Mapping the Geochemistry of the Earth's Land Surface

http://globalgeochemicalbaselines.eu.176-31-41-129.hs-servers.gr/datafiles/file/Blue_Book_GGD_IGCP259.pdf


Upper Continental Crust
Human blood
Here we see that our blood is composed from naturally occurring chemical elements (Demetriades et al., 2022a, Fig. 1.1, p.6).
Human blood: Logarithmic concentration in mg/l
Upper Continental Crust: Logarithmic concentration in mg/kg
Atomic number, Z

Mary Lou Zoback in her

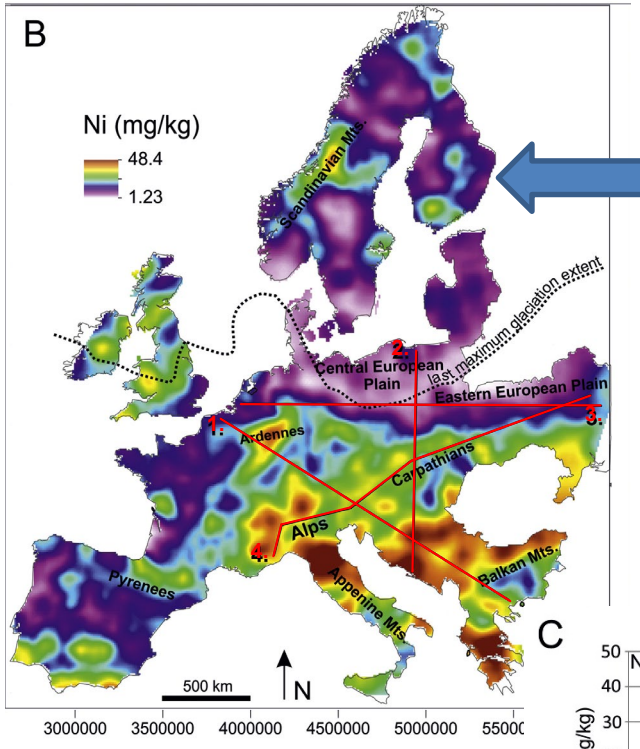
2000 Presidential Address:

Grand Challenges in Earth and Environmental Sciences: Science, Stewardship, and Service for the Twenty-First Century

stated ***"Documenting and understanding natural variability is a vexing topic in almost every environmental problem: How do we recognize and understand changes in natural systems if we don't understand the range of baseline levels?"*** (Zoback, 2001, p.41).

Source GSA Today, December 2001:
https://www.geosociety.org/gsatoday/archive/11/12/pdf/i1052-5173-11-12-41.pdf

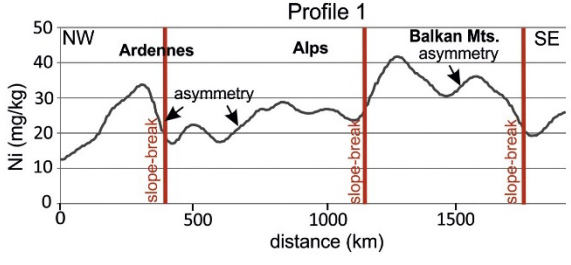
Variable geochemical baseline levels

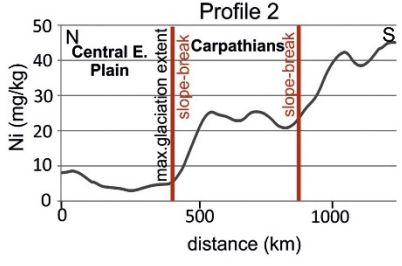


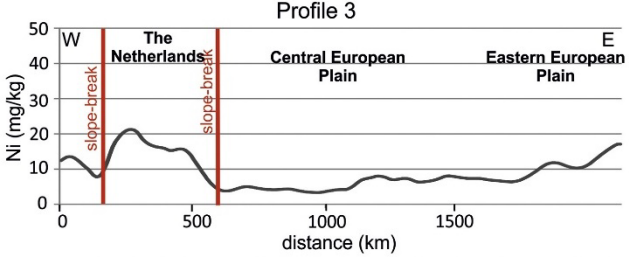
(Jordan *et al.*, 2018, Fig. 5, p.149)

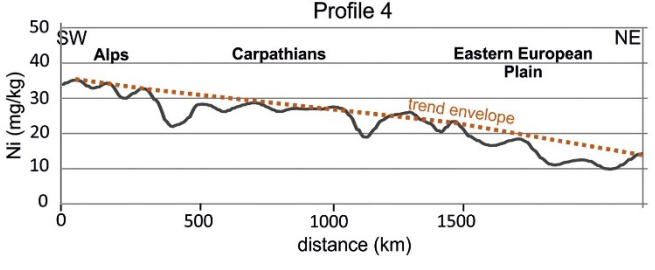
B. Interpolated Ni concentrations map with traces of cross-sections shown below.

C. Cross-sections of Ni concentrations made in different directions to capture the main spatial features. Large slope-breaks are shown with thick red lines and trend envelope with orange dashed line.





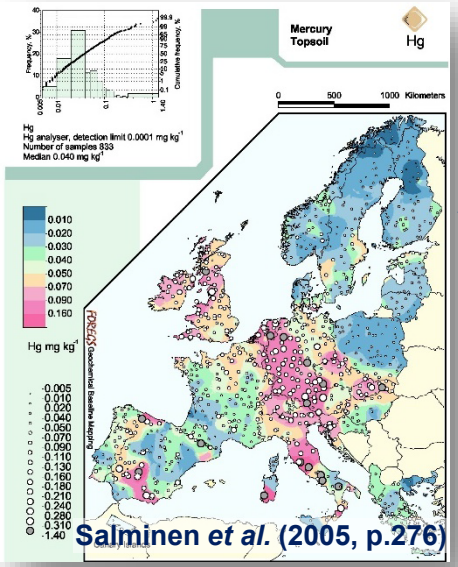




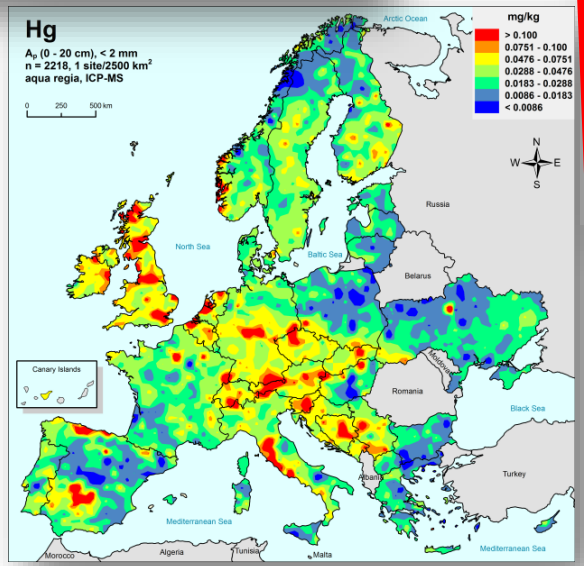
What continental-scale geochemical surveys are presently available?

Multinational

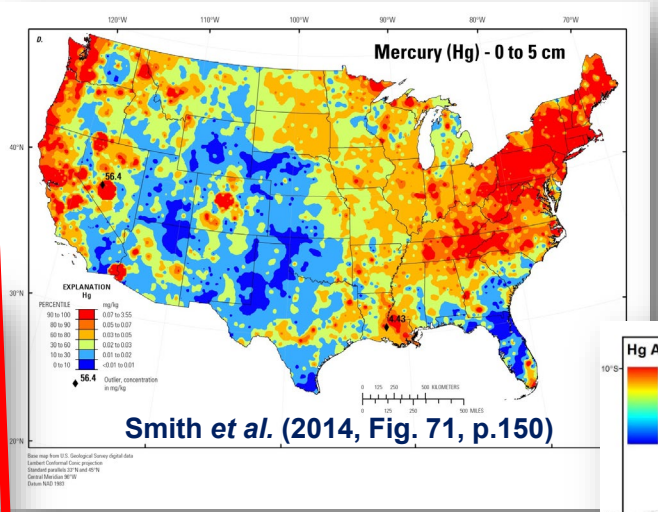
National geochemical projects



Salminen *et al.* (2005, p.276)

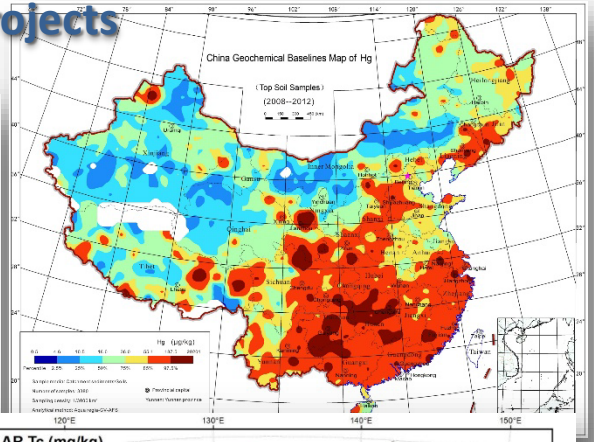


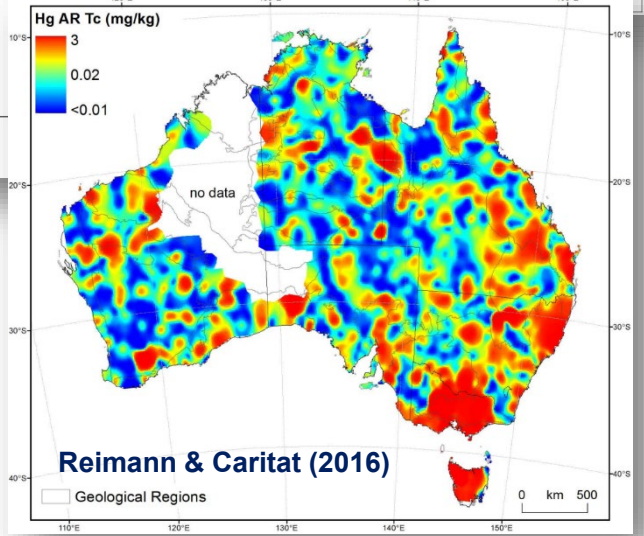
Reimann *et al.* (2014, Fig. 11.29.5, p.269)



Smith *et al.* (2014, Fig. 71, p.150)

Wang *et al.* (2015, Fig. 3, p.36)

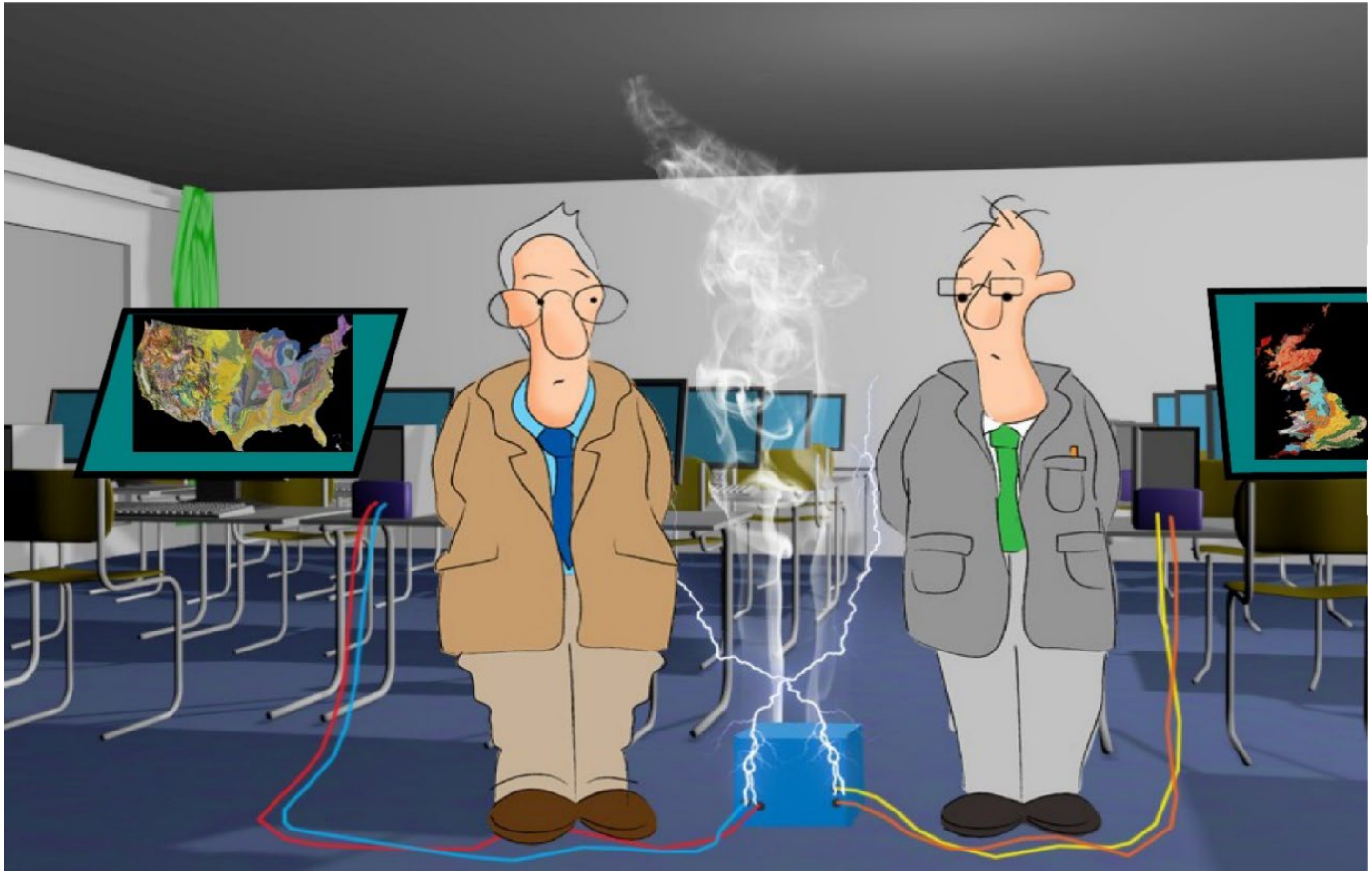




Reimann & Caritat (2016)

Further, there are ongoing national geochemical surveys in Mexico, Colombia, Peru, Argentina …..

Question 1: *Are geochemical data **interoperable** at the National and International scales?*



Source: EuroGeoSurveys (https://www.eurogeosurveys.org/)

Question 1: *Are geochemical data **interoperable** at the National and International scales?*

Answer 1: *Definitely NOT because of lack of standardised:-*

- *Sampling,*
- *Sample preparation,*
- *Quality control and*
- *Analytical protocols*

make it difficult to impossible to merge the existing geochemical data sets.

Question 2: How can standardisation and harmonisation of geochemical data be achieved at the National and International level?

Source: EuroGeoSurveys (https://www.eurogeosurveys.org/)

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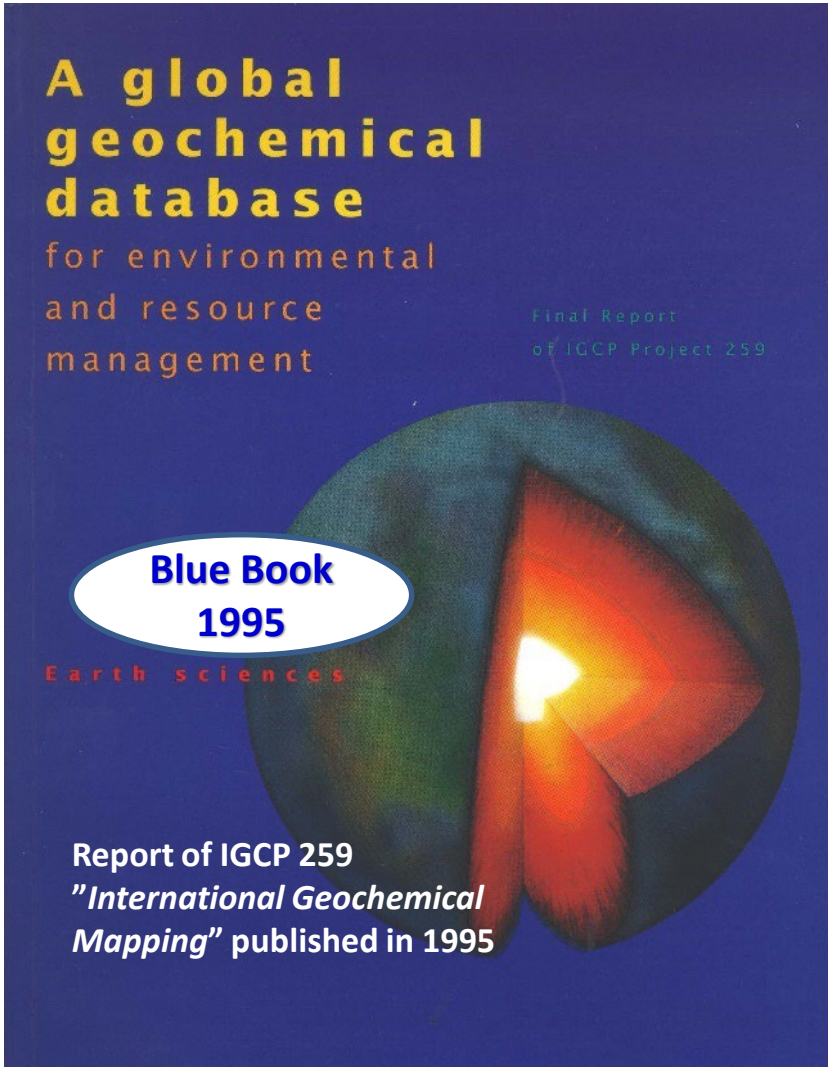
IUGS Commission on "Global Geochemical Baselines"

Mapping the Geochemistry of the Earth's Land Surface

Question 2: *How can **standardisation** and **harmonisation** of geochemical data be achieved at the National and International level?*

Answer 2: *The answer to the second question is given in the "**Blue Book**" and the recently published "**International Union of Geological Sciences Manual of Standard Methods for Establishing the Global Geochemical Reference Network**" for the production of internally consistent quality-controlled global geochemical data sets for multipurpose use.*



http://globalgeochemicalbaselines.eu.176-31-41-129.hs-servers.gr/datafiles/file/Blue_Book_GGD_IGCP259.pdf

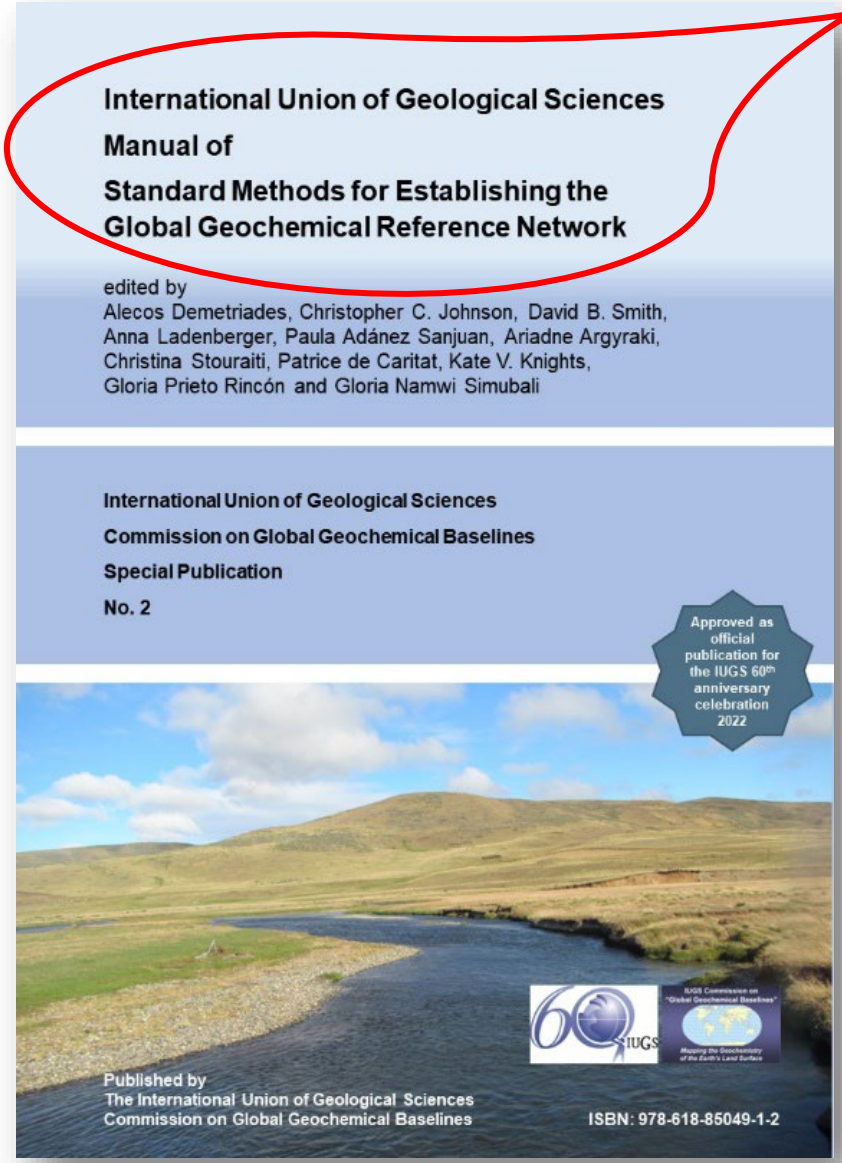
http://www.globalgeochemicalbaselines.eu/content/174/iugs-manual-of-standard-methods-for-establishing-the-global-geochemical-reference-network-/

Standardised procedures must be used:-

- Randomised sampling.
- Samples collected by the same procedure, using the same equipment.
- Samples prepared in the same laboratory, and
- Samples analysed in the same laboratory with the same analytical method or methods.

At all stages a strict quality controlled procedure must be installed.

All standardised procedures are described in:



The subject of this webinar:

Demetriades, A., Johnson, C.C., Smith, D.B., Ladenberger, A., Adánez Sanjuan, P., Argyraki, A., Stouraiti, C., Caritat, P. de, Knights, K.V., Prieto Rincón, G. & Simubali, G.N. (Editors), 2022. *International Union of Geological Sciences Manual of Standard Methods for Establishing the Global Geochemical Reference Network*. IUGS Commission on Global Geochemical Baselines, Athens, Hellenic Republic, Special Publication, 2, xliv, 515 pages, 375 figures, 35 Tables, 5 Annexes and 1 Appendix, ISBN: 978-618-85049-1-2; https://www.globalgeochemicalbaselines.eu/content/174/iugs-manual-of-standard-methods-for-establishing-the-global-geochemical-reference-network-/; https://doi.org/10.5281/zenodo.7307696.

International Union of Geological Sciences

Manual of

Standard Methods for Establishing the Global Geochemical Reference Network

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"Everything in and on the Earth - mineral, animal and vegetable - is made from one, or generally some combination of, the natural chemical elements occurring in the rocks of the Earth's crust and the surficial materials derived from them. Everything that is grown, or made, depends upon the availability of the appropriate elements. The existence, quality and survival of life depends upon the availability of elements in the correct proportions and combinations. Because natural processes and human activities are continuously modifying the chemical composition of our environment, it is important to determine the present abundance and spatial distribution of the elements across the Earth's surface in a much more systematic manner than has been attempted hitherto" (Darnley *et al.*, 1995, p.x). Although such a global database is urgently needed for multi-purpose use, the systematic attempt is still in its infancy because of the non-existence of a manual of comprehensive and standardised methods of sampling and other supporting procedures. The current ***'International Union of Geological Sciences Manual of Standard Methods for Establishing the Global Geochemical Reference Network'*** fills this gap. The Manual follows the concept of 7356 Global Terrestrial Network grid cells of 160x160 km, covering the land surface of Earth, with five random sites within each grid cell for the collection of samples. This allows the establishment of the *standardised Global Geochemical Reference Network* with respect to rock, residual soil, humus, overbank sediment, stream water, stream sediment and floodplain sediment. Apart from the instructions for the collection of samples, the Manual covers sample preparation and storage, development of reference materials, geoanalytical methods, quality control procedures, geodetic and parametric levelling of existing data sets, data conditioning for the generation of time-independent geochemical data, management of data and map production, and finally project management. The methods described herein, apart from their use for *Establishing the Global Geochemical Reference Network*, can be used in other geochemical surveys at any mapping scale.

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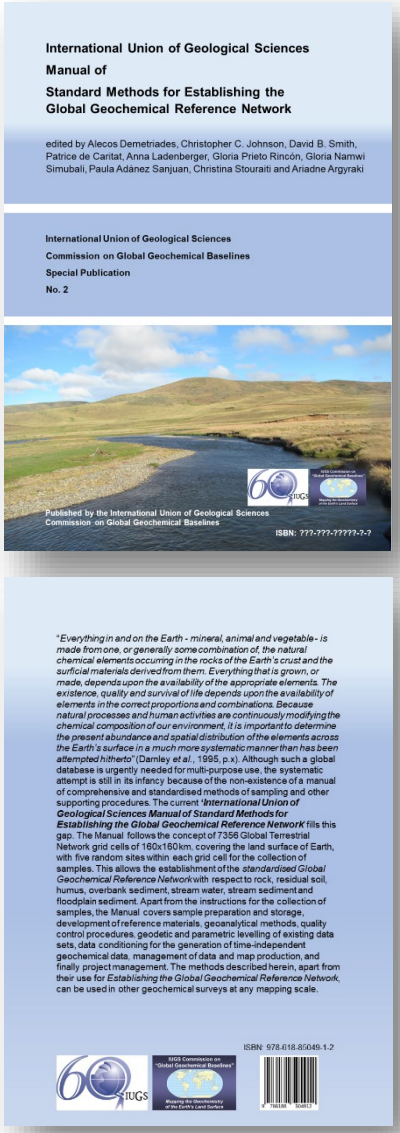
IUGS APPROVAL FOR PUBLICATION

The Executive Committee of the International Union of Geological Sciences at its 77th meeting in Paris (16-18 March 2022), unanimously approved the "***International Union of Geological Sciences Manual of Standard Methods for Establishing the Global Geochemical Reference Network***" to be published as a formal IUGS Publication for its 60th Anniversary celebration.

The IUGS Executive Committee members John Ludden (President), Hassina Mouri (Vice President), Daekyo Cheong (Vice President), Stanley C. Finney (Secretary-General), Hiroshi Kitazato (Treasurer), Qiuming Cheng (Past President), Silvia Peppoloni (Councillor), Claudia Inés Mora (Councillor), Jennifer McKinley (Councillor), and Ludwig Stroink (Councillor) are thanked for approving the publication of this Manual.



Contents of the Manual

- General Introduction
- Global Terrestrial Network Grid Cells, Selection of Sample Sites, and Samples to be Collected
- Sampling Methods:
  - Rock
  - Residual soil
  - Humus
  - Stream water
  - Stream sediments
  - Overbank & Floodplain sediments
- Geodetic Levelling of Existing Geochemical Data Sets
- Parametric Levelling of Existing Geochemical Data Sets
- Sample Preparation and Storage
- Development of Reference Materials for External Quality Control
- Geoanalytical Methods and Requirements
- Quality Control Procedures
- Data Conditioning Methods: Generating Time Independent Geochemical Data
- Data Management and Map Production
- Project Management
- Field Observation Sheets

51 contributors from 23 countries, and 23 peer reviewers from 13 countries.

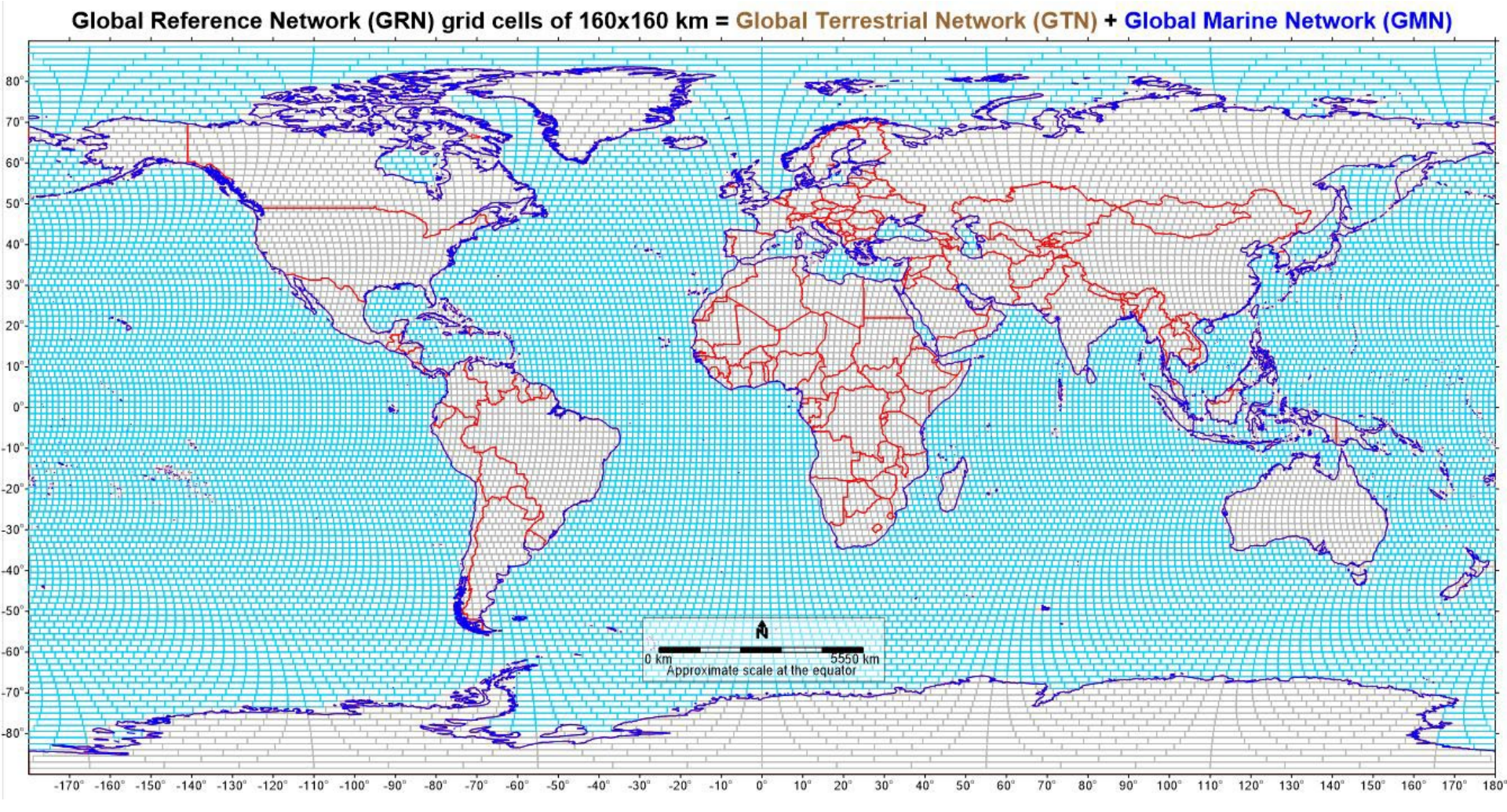
Question 3: ***How is the global-scale geochemical sampling campaign planned?***

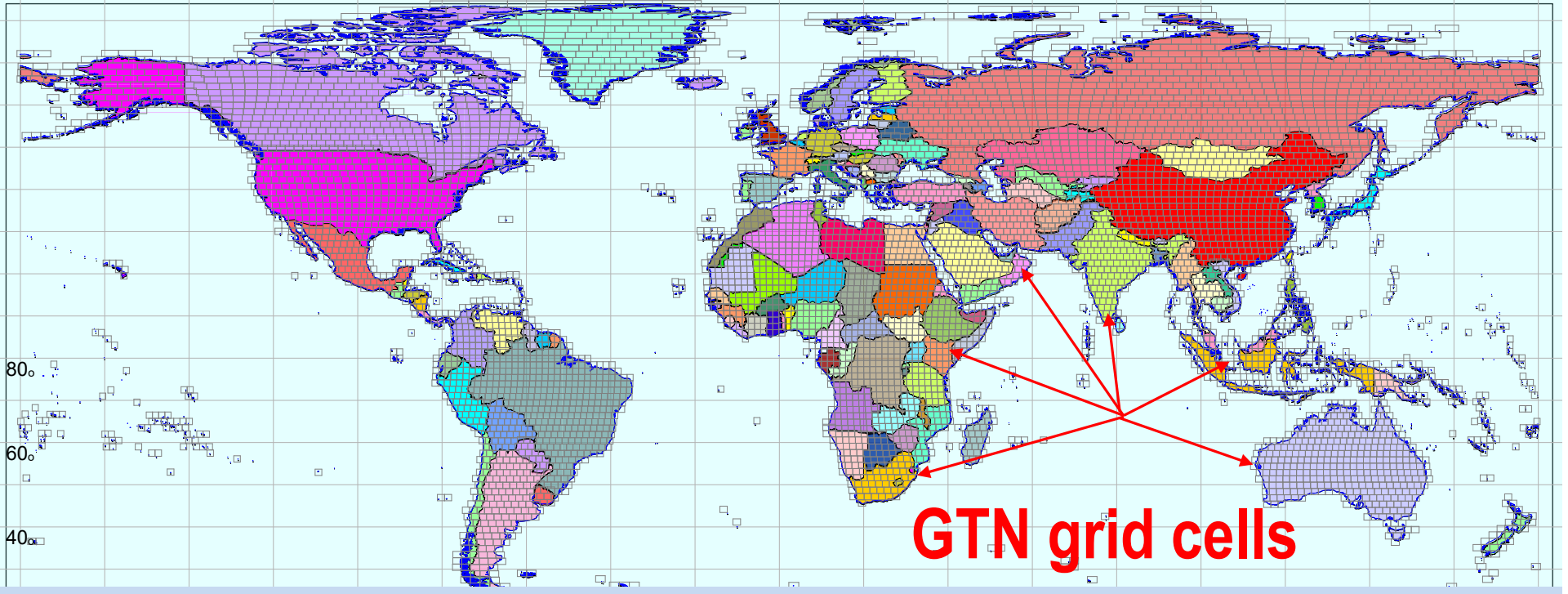
Answer 3: **The starting point is the Global Reference Network (GRN), which consists of 19,833 grid cells of 160x160 km.**

It consists of the:

- **Global Terrestrial Network (GTN) and**
- **Global Marine Network (GMN).**

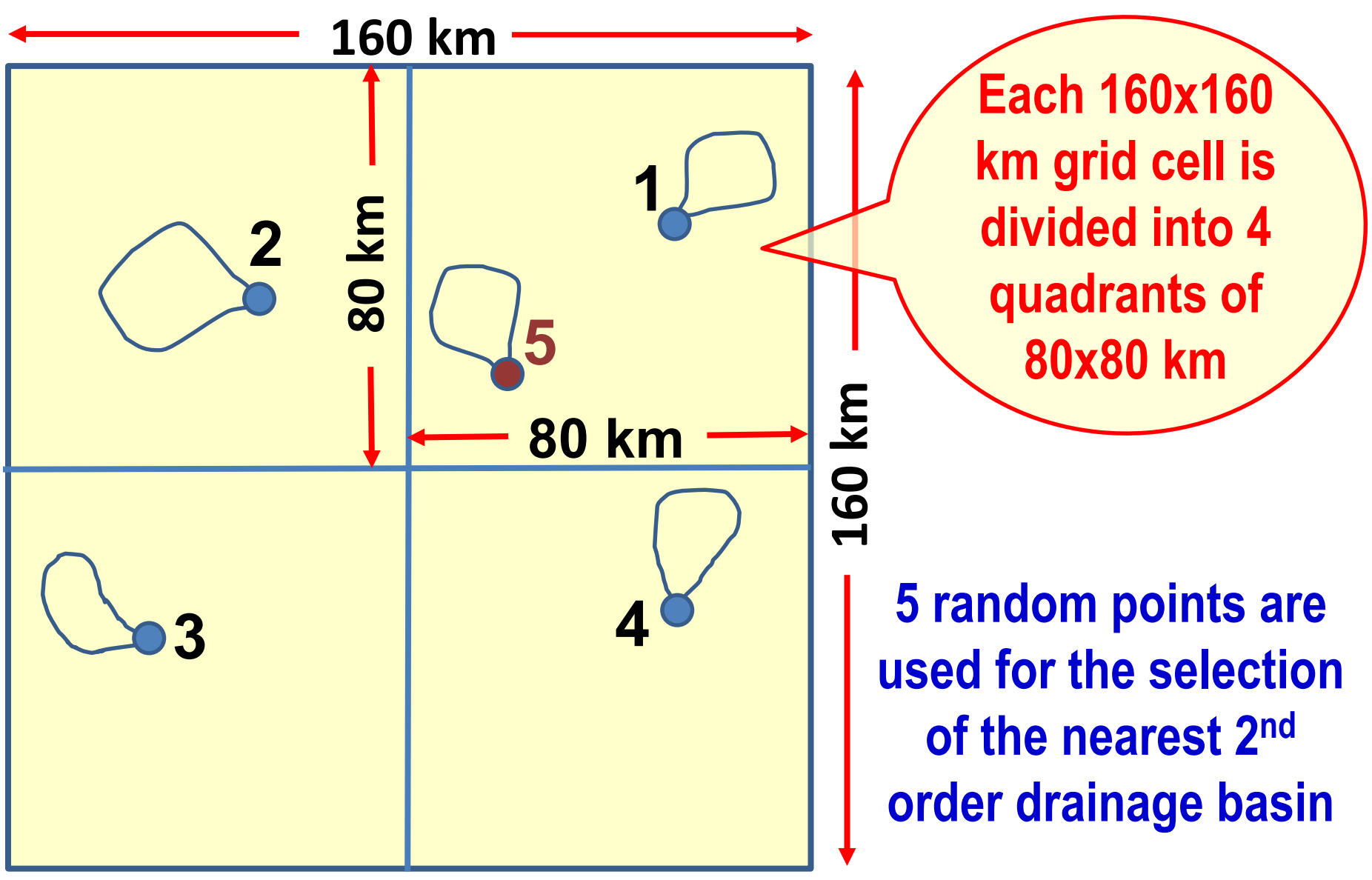
GLOBAL REFERENCE NETWORK GRID CELLS

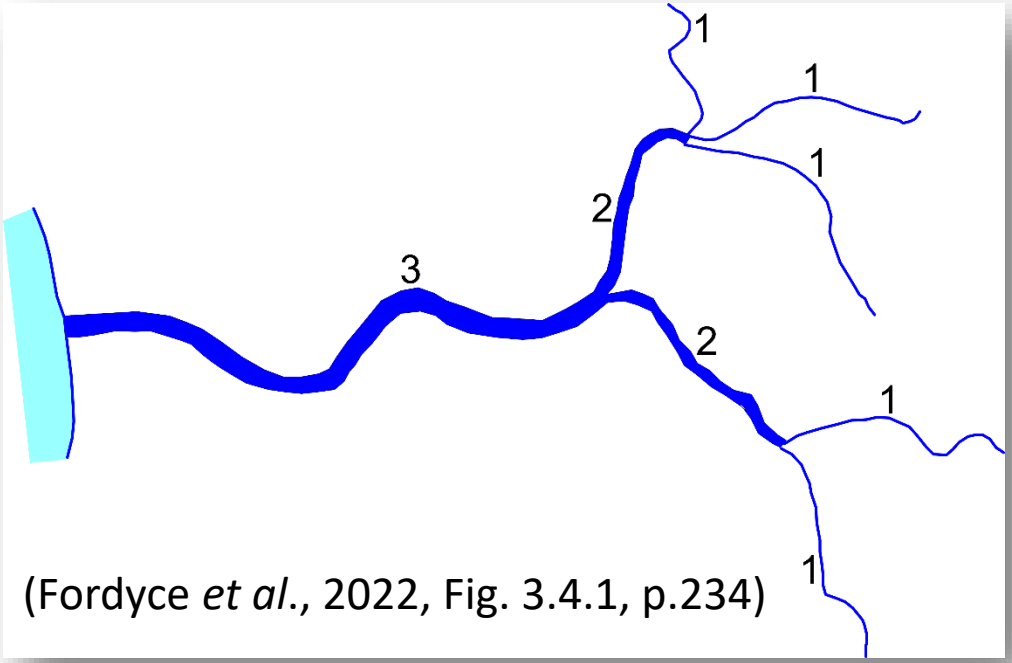




…..Answer 3…..: In our case, the starting point is the Global Terrestrial Network (GTN) grid cells.

The land surface of the Earth is covered by 7356 grid cells of 160x160 km.

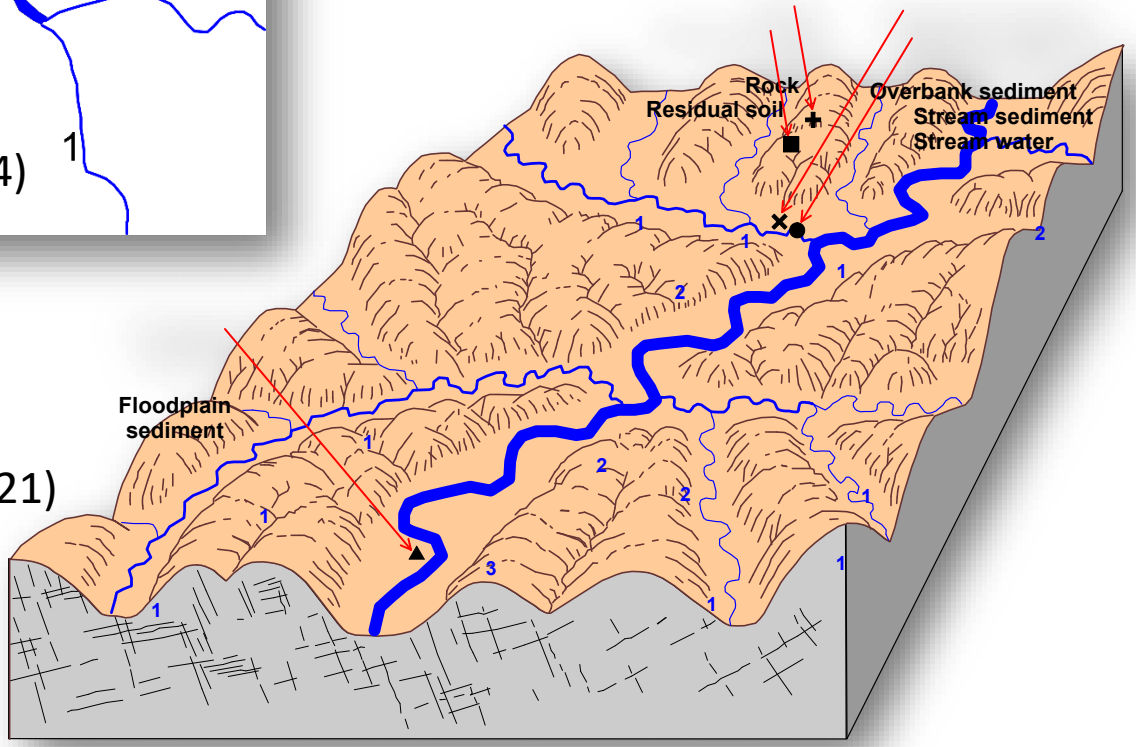

160 km
80 km
80 km
160 km
1
2
3
4
5
Each 160x160 km grid cell is divided into 4 quadrants of 80x80 km
5 random points are used for the selection of the nearest 2nd order drainage basin



(Fordyce *et al.*, 2022, Fig. 3.4.1, p.234)

On this slide the Strahler stream order classification system is explained

The mapping scale is 1:50,000



(Demetriades *et al.*, 2022b, Fig. 2.5, p.21)