2017
ANNUAL REPORT

of the

INTERNATIONAL UNION OF GEOLOGICAL SCIENCES COMMISSION ON GLOBAL GEOCHEMICAL BASELINES

January 2018

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IUGS COMMISSION ON GLOBAL GEOCHEMICAL BASELINES

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URL: www.globalgeochemicalbaselines.eu/

1. TITLE OF CONSTITUENT BODY

IUGS Commission on Global Geochemical Baselines (CGGB).

2. OVERALL OBJECTIVES

The mission of the Commission is to *(i)* prepare a global geochemical database and its representation in map form, and *(ii)* document the concentration and distribution of chemical elements and species in the Earth's near-surface environment. This database is urgently needed by environmental and natural resource managers throughout the world. To reach this goal, the Commission works with geochemists throughout the world to establish standards for global-scale geochemical mapping. The Commission also promotes and facilitates the implementation of harmonised sample collection, preparation, quality control, and analysis protocols for geochemical mapping programmes.

Commission activities include:

- Developing partnerships with countries conducting broad-scale geochemical mapping studies
- Providing consultation and training in the form of workshops and short courses to build the capacity for conducting geochemical mapping programmes in countries around the world
- Organising periodic international symposia and conferences to foster communication among the geochemical mapping community
- Developing standards for global-scale sampling in different morpho-climatic terranes
- Developing criteria for certifying those projects that are acceptable for inclusion in a global geochemical database
- Acting as a repository for data collected by projects meeting the standards of harmonisation
- Preparing complete metadata for the various certified projects
- Preparing a global geochemical database and atlas

3. RELATED GOALS TO OVERALL IUGS SCIENTIFIC OBJECTIVES

Current IUGS scientific policy objectives relate to global Earth Science issues, such as identification of mineral resources, global change, geological hazards, environmental geology and sustainable development. The work of the Commission relates directly to all of these objectives through the establishment of a land-surface global geochemical reference network, providing multi-media, multi-element baseline data for a wide variety of environmental and resource applications (Darnley et al., 1995). The project is also consistent with:

- The strategic plan published by the IUGS Strategic Planning Committee (2000)
- The International Year of Planet Earth (2007-2009) of *'Earth Sciences for Society'* (www.yearofplanetearth.org/)

- The objectives of IUGS Resourcing Future Generations initiative (iugs.org/index.php?page=resourcing-the-future-initiative)
- Work of the newly established UNESCO International Centre on Global-Scale Geochemistry (www.globalgeochemistry.com/)

4. STRUCTURE AND ORGANISATION

The Commission is led by a Steering Committee, which coordinates the activities of four Technical Committees as well as the contributions made by regional representatives. This organisation structure will be reviewed and if deemed necessary revised in 2018, as additional countries with active geochemical mapping programmes or an interest in establishing such programmes become members.

4.1. STEERING COMMITTEE

Co-Chairs	David B. Smith	US Geological Survey
	Xueqiu Wang	ICCG[1], China
Scientific Secretary	Patrice de Caritat	Geoscience Australia
Treasurer	Alecos Demetriades	Hellas

4.2. ANALYTICAL COMMITTEE

Chair Gwendy Hall Canada

Coordinates the work plan for the analysis of Global Reference Network (GRN) samples, the activities of the laboratories, and the supervision of analytical quality control data.

4.3. SAMPLING COMMITTEE

Chair Alecos Demetriades Hellas

Supervises the development and coordination of sampling protocols in the various climatic and geomorphological provinces throughout the world.

4.4. DATA MANAGEMENT COMMITTEE

Chair Timo Tarvainen Finland

Supervises the sampling strategy and progress of the participating countries, manages the database of sample information and analytical results.

4.5. PUBLIC RELATIONS AND FINANCE COMMITTEE

Chair Ariadne Argyraki Hellas

Advertises and promotes the aims, objectives and achievements of the project worldwide, including by use of the internet, and takes responsibility for trying to secure funding for the project.

4.6. REGIONAL REPRESENTATIVES

4.6.1. South America

Carlos Alberto Lins, CPRM - Geological Survey of Brazil, Recife - PE, Brazil

João H. Larizzatti, CPRM – Geological Survey of Brazil, Rio de Janeiro, Brazil

[1] UNESCO International Centre on Global-Scale Geochemistry

Juan Pablo Lacassie Reyes, Geological and Mining Survey of Chile, Santiago, Chile

Gloria Prieto, Servicio Geológico Colombiano, Bogotá, Colombia

4.6.2. Africa

Theo Davies, Mangosuthu University, Durban, South Africa

Marthinus Cloete and J.H Elsenbroek, Council for Geoscience, Pretoria, South Africa

Keith Sheppard, World Agroforestry Centre (ICRAF), Nairobi, Kenya

Alhaji Lamin Turay, Geological Survey Department, Ministry of Mineral Resources, Sierra Leone

4.6.3. Indian Subcontinent

Pradip Govil, National Geophysical Research Institute, Hyderabad, India

Mathew Joseph, Geological Survey of India, Kerala, India

Ashvin Wickramasooriya, South Eastern University of Sri Lanka, Sammanthurai, Sri Lanka

4.6.4. China

Xueqiu Wang, Institute of Geophysical and Geochemical Exploration, Langfang, China

4.6.5. Australasia

Patrice de Caritat, Geoscience Australia, Canberra

4.6.6. Japan

Atsuyuki Ohta, Geological Survey of Japan, AIST, Tsukuba

4.6.7. Europe

Clemens Reimann, Geological Survey of Norway, Trondheim, Norway

4.6.8. North America

David Smith, United States Geological Survey, Denver, USA

Enrique Espinosa, SGM, Pachuca, Mexico

Andy Rencz, Ottawa, Ontario, Canada

5. INTERACTION WITH OTHER INTERNATIONAL ORGANISATIONS AND PROJECTS

5.1. UNESCO INTERNATIONAL CENTRE ON GLOBAL-SCALE GEOCHEMISTRY

In May 2016, the UNESCO International Centre on Global-Scale Geochemistry (ICGG) opened in Langfang, China. The Commission was an active participant in preparing the successful proposal originally submitted to UNESCO in 2009.

One of the most important tasks for the new Commission is to establish formal collaboration with the UNESCO Centre.

Although there is considerable overlap in the objectives of the Commission and the Centre, the

IUGS mandate is quite clear, namely that the Commission takes the lead in establishing the standards for global-scale geochemical mapping, in collaboration with the Centre; whereas, the Centre takes the lead in implementing those standards, in collaboration with the Commission. There will be close collaboration between the Centre and the Commission with respect to the initiative of the International Scientific Cooperation Project of Mapping the Chemical Earth by the Centre and the Global Geochemical Baselines coverage according to IGCP 259 specifications. It is, of course, essential that the two bodies work to support each other in the pursuit of the aforementioned objectives (Section 2). The collaboration is expected to be smooth as the Commission's Steering Committee are members of the Centre's Governing Board and Scientific Committee.

5.2. INTERFACE WITH OTHER INTERNATIONAL ORGANISATIONS AND PROJECTS

This project is closely associated with the work of the EuroGeoSurveys (EGS) Geochemistry Expert Group (previously the Forum of European Geological Surveys, FOREGS Geochemistry Expert Group). The project also has links with the International Atomic Energy Agency (IAEA) and potential links with the Global Terrestrial Observing System (GTOS). The EGS Geochemistry Expert Group has also established closer links with the European Soil Bureau Network (ESBN) over the past few years, and was actively involved in the European Union's (EU) Soil Thematic Strategy group for the preparation of the EU's Soil Protection Document, and the final draft of the pending Soil Protection Directive.

The EGS Secretary General has established links to other European Commission projects, such as the Global Monitoring of Environment and Security (GMES) programme, and Infrastructure for Spatial Information in Europe (INSPIRE), since the Geochemical Atlas of Europe has been produced in a harmonised manner according to IGCP 259 specifications (Darnley et al., 1995) and, therefore, compliant with INSPIRE guidelines.

In 2013, EGS became member of the United Nations Food and Agricultural Organization's (FAO) Global Soil Partnership, since the Geological Surveys of Europe are actively involved in soil geochemical mapping. A Memorandum of Understanding (MoU) has been signed by EGS and the European Commission Joint Research Centre at Ispra (northern Italy), and representatives of the two institutions met at the end of January 2014 to discuss and finalise the cooperation.

In 2014, the Commission established links with the Young Earth Scientists Network during the 1st International Geosciences Congress organised by the Geological Survey of Iran in Tehran (February 2014). This collaboration resulted in the organisation of two two-day workshops on *"Global Geochemical Baselines"* during the 3rd YES Congress in Tanzania (August 2014) and the 4th YES Congress in Iran (August 2017), as detailed in Section 7.2. This collaboration is continuing with the organisation of a workshop on the occasion of the RFG2018 Conference in Vancouver, Canada (June 2018). There is also a discussion about the establishment of a YES Working Group on Applied Geochemistry.

EuroGeoSurveys also established cooperation with the Organisation of African Geological Surveys (OAGS) and developed a pan-African geological project proposal (PanAfGeo), which is financed by the European Commission. The project proposal was presented at a workshop on 14 August 2014 in Dar es Salaam (Tanzania), and the final results were presented at the OAGS Director's meeting in Gaborone (Botswana), 13-16 October 2014. The two-year joint project will cover a fairly wide range of tasks, starting from the issues of geoscientific mapping and sustainable management of mineral resources, to human resources and training needs for OAGS members and their partners through innovative case studies. The first results of this project were presented at a dedicated session of the 35th International Geological Congress (35th IGC) in Cape Town in August 2016.

EuroGeoSurveys is participating in GEO-CRADLE (Coordinating and integRating state-of-the-art Earth Observation Activities in the regions of North Africa, Middle East, and Balkans and Developing Links with GEO related initiatives towards GEOSS), a European Commission Horizon-2020 funded project. The results of both the FOREGS and GEMAS (GEochemical Mapping of Agricultural and grazing land Soil of Europe) projects are used by this project.

The Commission submitted in August 2015 a joint proposal entitled "*Africa Global-scale Geochemical Baselines for mineral resource and environmental management: Capacity building phase*" to the Group on Earth Observations (AfriGEOSS) with the EGS Geochemistry Expert Group, the Geological Society of Africa and the Organisation of African Geological Surveys (see Section 7.1.2 for more detail).

In North America, the project has established links with the North American Soil Geochemical Landscapes Project involving the Geological Survey of Canada (GSC), the United States Geological Survey (USGS), and the Servicio Geológico Mexicano (SGM).

The Commission also interfaces with the National Geochemical Survey of Australia and the China Geochemical Baselines projects.

The Commission contributed to the IUGS initiative's Resourcing Future Generations (RFG) by submitting comments in July 2015 on the White Paper *"Resourcing Future Generations: Mineral Resources and Future Supply"* in collaboration with the EGS Geochemistry and Mineral Resources Expert Groups. Also participated with a representative in the RFG workshop in Namibia (24-30 July 2015), and is organising a session in RFG2018 in Vancouver on *"Global-Scale Geochemical Mapping: A Critical Component for Resourcing Future Generations"*.

6. CHIEF PRODUCTS IN 2017

6.1. ARTICLES, PAPERS, ATLASES AND BOOKS

Ali, S.H., Giurco, D., Arndt, N., Nickless, E., Brown, G., Demetriades, A., Durrheim, R., Enriquez, M.A., Kinnaird, J., Littleboy, A., Meinert, L.D., Oberhänsli, R., Salem, J., Schodde, R., Schneider, G., Vidal, O. & Yakovleva, N., 2017. Mineral supply for sustainable development requires resource governance. Nature (Perspectives), 543: 367-372. doi: 10.1038/nature21359.

Anonymous, 2017. GSWA 2017 Extended abstracts: promoting the prospectivity of Western Australia. Geological Survey of Western Australia Record 2017/2. Available at: www.dmp.wa.gov.au/ebookshop

Birke, M., Reimann, C., Rauch, U., Ladenberger, A., Demetriades, A., Jähne-Klingberg, F., Oorts, K., Gosar, M., Dinelli, E., Halamic, J. & The GEMAS Project Team, 2017. GEMAS: Cadmium distribution and its sources in agricultural and grazing land soil of Europe - original data versus clr-transformed data. Journal of Geochemical Exploration, 173: 13-30. doi: 10.1016/j.gexplo.2016.11.007.

Caritat, P. de & Reimann, C., 2017. Publicly available datasets on thallium (Tl) in the environment – a comment on *"Presence of thallium in the environment: sources of contaminations, distribution and monitoring methods"* by Bozena Karbowska, Environ Monit Assess (2016) 188:640 (DOI 10.1007/s10661-016-5647-y). Environmental Monitoring and Assessment, 189: 232. doi: 10.1007/s10661-017-5945-z.

Caritat, P. de, Main, P.T., Grunsky, E.C. & Mann, A., 2017. Recognition of geochemical footprints of mineral systems in the regolith at regional to continental scales. Australian Journal of Earth Sciences, 64: 1033-1043. doi: 10.1080/08120099.2017.1259184.

Cracknell, M.J. & Caritat, P. de, 2017. Catchment-based gold prospectivity analysis combining geochemical, geophysical and geological data across northern Australia. Geochemistry: Exploration, Environment, Analysis, 17: 204-216. doi: 10.1144/geochem2016-012.

Fabian, K., Reimann, C. & Caritat, P. de, 2017. Quantifying diffuse contamination: method and

application to Pb in soil. Environmental Science & Technology, 51: 6719-6726. doi: 10.1021/ACS.EST.7B00741.

Grunsky, E.C., Caritat, P. de & Mueller, U.A., 2017. Using surface regolith geochemistry to map the major crustal blocks of the Australian continent. Gondwana Research, 46: 227-239. doi: 10.1016/j.gr.2017.02.011.

Haines, P.W. & Allen, H.J., 2017. Geological reconnaissance of the southern Murraba Basin, Western Australia. Geological Survey of Western Australia Record 2017/4. Available at: www.dmp.wa.gov.au/ebookshop

Hron, K., Filzmoser, P., Caritat, P. de, Fišerová, E. & Gardlo, A., 2017. Weighted pivot coordinates for compositional data and their application to geochemical mapping. Mathematical Geoscience, 49: 797-814. doi: 10.1007/s11004-017-9684-z.

Jauss, V., Sullivan, P.J., Sanderman, J., Smith, D.B. & Lehmann, J., 2017. Pyrogenic carbon distribution in mineral topsoils of the northeastern United States. Geoderma, 296: 69-78. doi: 10.1016/j.geoderma.2017.02.022.

Martin, A.P., Ohneiser, C., Turnbull, R.E., Strong, D.T. & Demler, S., 2017. Soil magnetic susceptibility mapping as a pollution and provenance tool: an example from southern New Zealand. Geophysical Journal International, Online first. doi: 10.1093/gji/ggx484.

Martin, A.P., Strong, D.T., Rattenbury, M.S., Turnbull, R.E., Durance, P.M.J., Stucker, V.K. & Morgenstern, R., 2017. Soil geochemistry for mineral exploration in Otago-northern Southland. In: Fergusson, D. (convener), Australasian Institute of Mining and Metallurgy 50th New Zealand Branch Annual Conference (Christchurch, New Zealand, 10-13 September 2017), 381-390.

Martin, A.P., Turnbull, R.E., Rattenbury, M.S., Strong, D.T. & Ries, W.F., 2017. Mineral exploration opportunities identified from new soil geochemistry over mafic and ultramafic rocks of the Richmond Range, Nelson. In: Fergusson, D. (convener), Australasian Institute of Mining and Metallurgy 50th New Zealand Branch Annual Conference (Christchurch, New Zealand, 10-13 September 2017), 164-173.

Martin, A.P., Turnbull, R.E., Rissmann, C.W. & Rieger, P., 2017. Heavy metal and metalloid concentrations in soils under pasture of southern New Zealand. Geoderma Regional, 11: 18-27. doi: 10.1016/j.geodrs.2017.08.005.

Morris, P., 2017. Potential for SEDEX-style mineralization in the Ngururrpa area of northeastern Western Australia. Fieldnotes: A Geological Survey of Western Australia Newsletter), Oct 2017: 5. Available at: www.dmp.wa.gov.au/ebookshop

Reimann, C. & Caritat, P. de, 2017. Establishing geochemical background variation and threshold values for 59 elements in Australian surface soil. The Science of the Total Environment, 578: 633-648. doi: 10.1016/j.scitotenv.2016.11.010.

Rogers, K.M., Turnbull, R.E., Martin, A.P., Baisden, W.T. & Rattenbury, M.S., 2017. Stable isotopes reveal human influences on southern New Zealand soils. Applied Geochemistry, 82: 15-24. doi: 10.1016/j.apgeochem.2017.05.006.

Smith, D.B., Wang, X., Demetriades, A. & Caritat, P. de, 2017. Global-scale geochemical baselines mapping: steps forward in 2016. Explore (Newsletter for the Association of Applied Geochemists), 174 (Mar 2017): 19-21.

Smith, D.B., Wang, X., Demetriades, A., Caritat, P. de & Yao, W., 2017. Historical outline of global geochemical baselines leading to the establishment of the UNESCO International Centre on Global-Scale Geochemistry. Chemical Earth (Newsletter of UNESCO International Centre on Global-Scale Geochemistry), 1 (Dec 2017): 18-22.

Turnbull, R.E., Martin, A.P., Strong, D.T., Rattenbury, M.S., Morgenstern, R., Ries, W.F., Stucker, V.K. & Durance, P.M.J., 2017. Soil geochemical survey of the Rotoroa Complex: implications for mineral exploration. In: Fergusson, D. (convener), Australasian Institute of Mining and Metallurgy 50th New Zealand Branch Annual Conference (Christchurch, New Zealand, 10-13 September 2017), 391.

Waldrop, M.P., Holloway, J.M., Smith, D.B., Goldhaber, M.B., Drenovsky, R.E., Scow, K.M., Dick, R., Howard, D., Wylie, B. & Grace, J.B., 2017. The interacting roles of climate, soils, and plant production on soil microbial communities at a continental scale. Ecology, 98: 1957-1967. doi: 10.1002/ecy.1883.

6.2. ORAL AND POSTER PRESENTATIONS

Environmental Analytical Chemistry of TCEs, the COST Action TD1407 Workshop on Environmental Concentrations, Cycling and Modelling of Technology-Critical Elements, David Lopatie Conference Center of the Weizmann Institute of Science, Rehovot, Israel (https://www.costnotice.net/ws), 18-19 January 2017

Reimann, C., 2017. *Multi-element, multi-media geochemistry: the key for understanding element cycling in the ecosystem*.

Reimann, C., 2017. *Statistical analysis and processing of geochemical data*.

MineWat2017: 2nd International Multidisciplinary Conference on Mineral Waters: Genesis, Exploitation, Protection and Valorisation, Vila de Luso, Portugal (http://www.minwatportugal2017.org/), 26-31 March 2017

João Batista, M., Lorenço, C., Reimann, C., Birke, M., Demetriades, A. & EGG Team, 2017. *European Groundwater Geochemistry (EGG): European and Portuguese bottled water used for groundwater characterisation.*

EuroGeo Surveys Geochemistry Expert Group and IUGS Commission on Global Geochemical Baselines Meeting, Vienna, Austria, 20-21 April 2017

Demetriades, A., Smith, D., Wang, X. & Caritat, P. de, 2017. *IUGS Commission on Global Geochemical Baselines and its relationship with the UNESCO International Centre on Global-Scale Geochemistry*.

Simubali G., 2017. *Regional geochemical mapping in Namibia*.

European Geosciences Union (EGU) General Assembly 2017, Vienna, Austria, 23-28 April 2017

Birke, M., Reimann, C., Ladenberger, A., Négrel, P., Rauch, U., Demetriades, A., Korte, F., Dinelli, E. & the GEMAS Project Team, 2017. *GEMAS: Geochemical distribution of iodine in European agricultural soil*.

Cicchella, D., Zuzolo, D., Demetriades, A., De Vivo, B., Eklund, M., Ladenberger, A., Négrel, P. & O'Connor, P., 2017. *GEMAS: Molybdenum spatial distribution patterns in European soil*.

Fabian, K., Reimann, C. & Caritat, P. de, 2017. *A new method for detecting, quantifying and monitoring diffuse contamination.*

Filzmoser, P., Kynclova, P., Hron, K. & Reimann, C., 2017. *Correlation between variables in compositional data.*

Hoogewerff, J., Reimann, C., Ueckermann, H., Frei, R., Frei, K., Aswegen, T. van, Stirling, C., Reid, M., Clayton, A. & GEMAS Project Team, 2017. *A preliminary bioavailable strontium isotope soil map of Europe*.

Jordan, G., Petrik, A., De Vivo, B., Albanese, S., Demetriades, A. & Sadeghi, M., 2017. *GEMAS: Spatial pattern analysis of Ni by using digital image processing techniques on European agricultural soil data*.

Négrel, P. & Haslinger, E., Conveners, 2017. *Session SSS3.5: Geochemical mapping at all scales: evidence from soil, sediment, water and plants.*

Négrel, P., Reimann, C., Ladenberger, A., Birke, M. & GEMAS Project Team, 2017. *Distribution of lithium in agricultural and grazing land soils at European continental scale*.

Reimann, C., 2017. *Regional Geochemistry – An Introduction*.

Reimann, C., Fabian, K., Birke, M., Demetriades, A., Matschullat, J. & GEMAS Project Team, 2017. *GEMAS: Geochemical mapping of the agricultural and grazing land soils of Europe*.

Critical Zone Science Conference, Arlington, VA, USA, 4-6 June 2017

Bui, E.N., Wilford, J.R. & Caritat, P. de, 2017. *Predictive spatial geochemical modelling of the Australian Critical Zone from local to continental scales*.

7th International Workshop on Compositional Data Analysis, Siena, Italy (http://www.compositionaldata.com/codawork2017/), 5-9 June 2017

Demetriades, A. & Buccianti, A., 2017. *Compositional data analysis: the applied geochemist and the compositional data analyst*.

Hron, K., Filzmoser, P., Caritat, P. de, Fišerová, E. & Gardlo, A., 2017. *Weighted pivot balances: simulations and application to geochemical mapping.*

Goldschmidt Conference 2017, Paris, France (https://goldschmidt.info/2017/), 13-18 August 2017

Caritat, P. de & Rate, A.W., 2017. *Detecting anomalous metal concentrations in the regolith using cross–compositional detrending.*

Caritat, P. de, 2017. *Geochemical exploration through cover: past, present, and future.*

Reimann, C., 2017. *Geochemical background and threshold for emerging inorganic contaminants at the European scale*.

4th YES Congress on Mitigating Geohazards and Resources for Future Generations, Geological Survey of Iran, Tehran, Iran (http://conf.yesnetwork.ir/index.php), 27-30 August 2017

Demetriades, A., Smith, D.B., Wang, X., Caritat, P. de, 2017. *Global Geochemical Baselines for environmental and mineral resource management: Iran and neighbouring countries*.

18th Annual Conference of the International Association for Mathematical Geosciences, Fremantle, Western Australia, 2-9 September 2017

Main, P. & Caritat, P. de, 2017. *Principal component analysis of low-density geochemical data from the southern Thomson Orogen*.

Australasian Institute of Mining and Metallurgy (AusIMM) 50th New Zealand Branch Annual Conference, Christchurch, New Zealand, 10-13 September 2017

Martin, A.P., Strong, D.T., Rattenbury, M.S., Turnbull, R.E., Durance, P.M.J., Stucker, V.K. & Morgenstern, R., 2017. *Soil geochemistry for mineral exploration in Otago-northern Southland.*

Martin, A.P., Turnbull, R.E., Rattenbury, M.S., Strong, D.T. & Ries, W.F., 2017. *Mineral exploration opportunities identified from new soil geochemistry over mafic and ultramafic rocks of the Richmond Range, Nelson.*

Turnbull, R.E., Martin, A.P., Strong, D.T., Rattenbury, M.S., Morgenstern, R., Ries, W.F., Stucker, V.K. & Durance, P.M.J., 2017. *Soil geochemical survey of the Rotoroa Complex: implications for mineral exploration.*

Exploration '17, Toronto, Canada, 22-25 October 2017

Grunsky, E.C. & Caritat, P. de, 2017. *Advances in the use of geochemical data for regional exploration.*

Geo-variety Inheritance for the Future, workshop organised by the Retirees Union of the Institute of Geology and Mineral Exploration, Athens, 3 December 2017

Demetriades, A., 2017. *The three Geochemical Atlases of Europe.*

1st Ice-Breaking Workshop on Global Black Soil Critical Zone Geo-ecological Survey (BASGES), Shenyang Geological Survey, Shenyang, China, 8-12 December 2017

Birke, M., Reimann, C., Demetriades, A., Rauch, U. & the GEMAS Project Team, 2017. EuroGeoSurveys GEMAS Research: a review and future prospects.

Demetriades, A. & the EuroGeoSurveys Geochemistry Expert Group's FOREGS Team, 2017. *WEGS and FOREGS Geochemical mapping of Europe*.

Demetriades, A., Smith, D.B. & Caritat, P. de, 2017. *Input to BASGES project by the IUGS Commission on Global Geochemical Baselines* (see Appendix A).

7. CHIEF ACCOMPLISHMENTS IN 2017

7.1. SCIENTIFIC ACCOMPLISHMENTS

There has been continued and significant progress in a number of areas during 2017, as detailed in the following.

7.1.1. The Americas

NORTH AMERICA (David B. Smith, USGS)

The USGS published *The Geochemical Atlas of Alaska* (Lee et al., 2016). This atlas is based on data compiled from legacy databases of the USGS and the Alaska Division of Geological and Geophysical Surveys. The data represent chemical analyses of more than 175,000 samples of soil and stream sediments, some dating back to the 1960s. Various types of heterogeneity and deficiencies in these data presented major challenges to the development of coherently integrated datasets for modelling and mapping of element distributions. Researchers from many different organizations and disparate scientific studies collected samples that were analysed using highly variable methods throughout a period of more than 50 years, during which many changes in analytical techniques were developed and applied. Despite these challenges, the USGS has produced a new systematically integrated compilation of sediment and soil geochemical data with an average sample density of approximately 1 site per 10 km^2 for the entire State of Alaska (1.7 million km^2), although density varies considerably among different areas. From that compilation, the authors have modelled and mapped the distributions of 68 elements, thus creating an updated geochemical atlas for the State. The publication, including all geochemical maps, can be downloaded from https://pubs.er.usgs.gov/publication/ds908.

SOUTH AMERICA

Brazil (João H. Larizzatti, CPRM)

The Geological Survey of Brazil (CPRM) has been conducting low-density geochemical mapping since 2008. By the end of 2017, approximately 40% of the country was sampled, and more than 20,000 samples were collected. The States of São Paulo (SP), Minas Gerais (MG), Espírito Santo (ES), Ceará (CE), Pernambuco (PE), Paraíba (PB), Alagoas (AL), and Mato Grosso do Sul (MS) were wholly covered; MS has a permanent flooded area called Pantanal that was not sampled. The States of Roraima, Pará, Bahia and Rio de Janeiro were partially covered (Figure 1).

In 2016, CPRM started working in the Cabeça do Cachorro region (Head of the Dog). The region presents very difficult access; there are no roads and the sampling area can only be reached by boat or helicopter. The sampling programme includes soil, stream sediment, stream water and heavy mineral concentrates. Figure 2 shows the area covered during 2016 and 2017. In total, the different sample types collected were 153 stream water, 27 soil, 151 stream sediment and 137 heavy mineral concentrates. A CPRM team based in Manaus (Amazonas State) is carrying out this project, and this opportunity is used to train the sampling teams in the Amazonian environment.

CPRM has an MoU with China Geological Survey, and is in touch with Prof. Xueqiu Wang from the UNESCO International Centre on Global-Scale Geochemistry in Langfang, China, in order to adapt the work to international standards.

CPRM is also working together with ASGMI (Association of Geological Survey of Latin Countries) in order to start Low Density Geochemical Mapping of South America.

For the next year, CPRM intends to continue the sampling programme in NW Brazil and complete the sampling in NE Brazil (Rio Grande do Norte State).

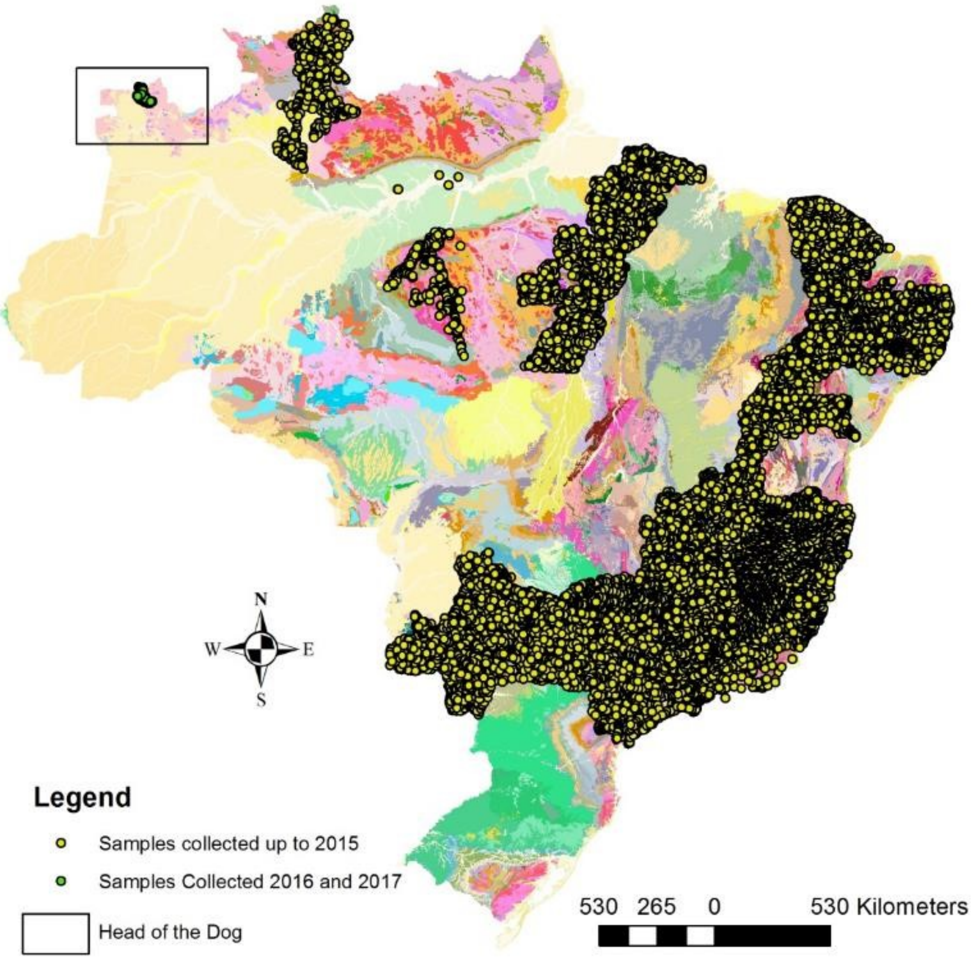


Figure 1. Low-density geochemistry sampling, Brazil.

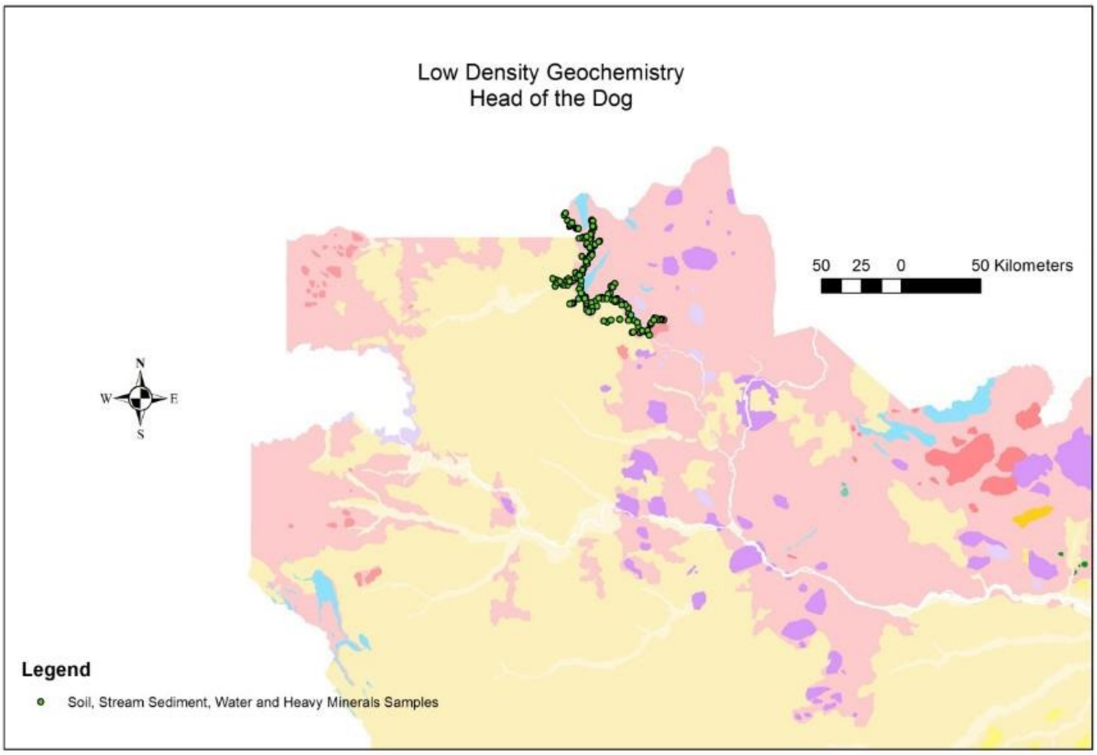


Figure 2. Low-density sampling at Head of the Dog region, Brazil.

Colombia ***(Gloria Prieto, Servicio Geológico Colombiano)***

During 2017, the Geological Survey of Colombia (SGC) continued its geochemical survey programme at different sampling densities with the objective to produce geochemical information in Colombia for geochemical studies, mineral exploration, geomedicine, environment, and geological mapping.

Geochemical Atlas of Colombia

Different geochemical studies developed by the Geological Survey of Colombia allowed the compilation of geochemical information for the Geochemical Atlas of Colombia (AGC) that was initiated in 2016 and published in 2017. The Geochemical Atlas includes 56 chemical elements (Figures 3, 4), and was generated by integration of geochemical data from more than 70,000 stream sediment samples.

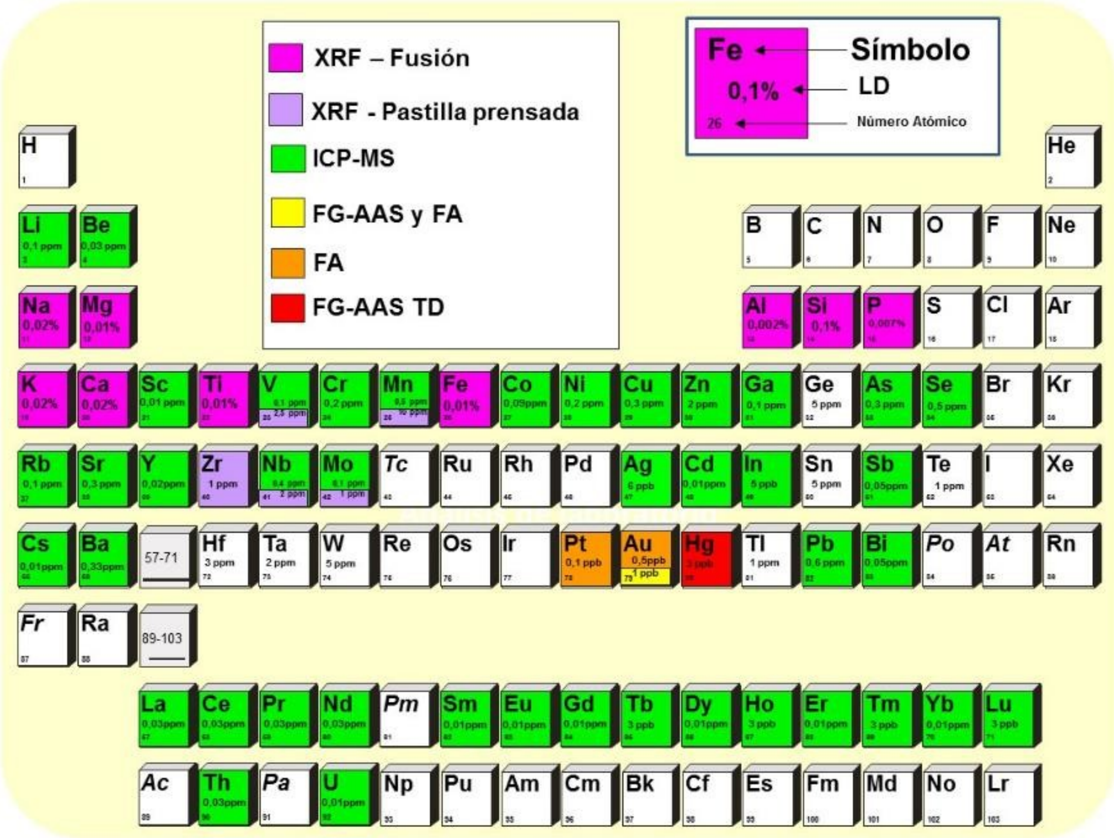


Figure 3. Highlighted in colour are the 56 elements included in the Geochemical Atlas of Colombia.

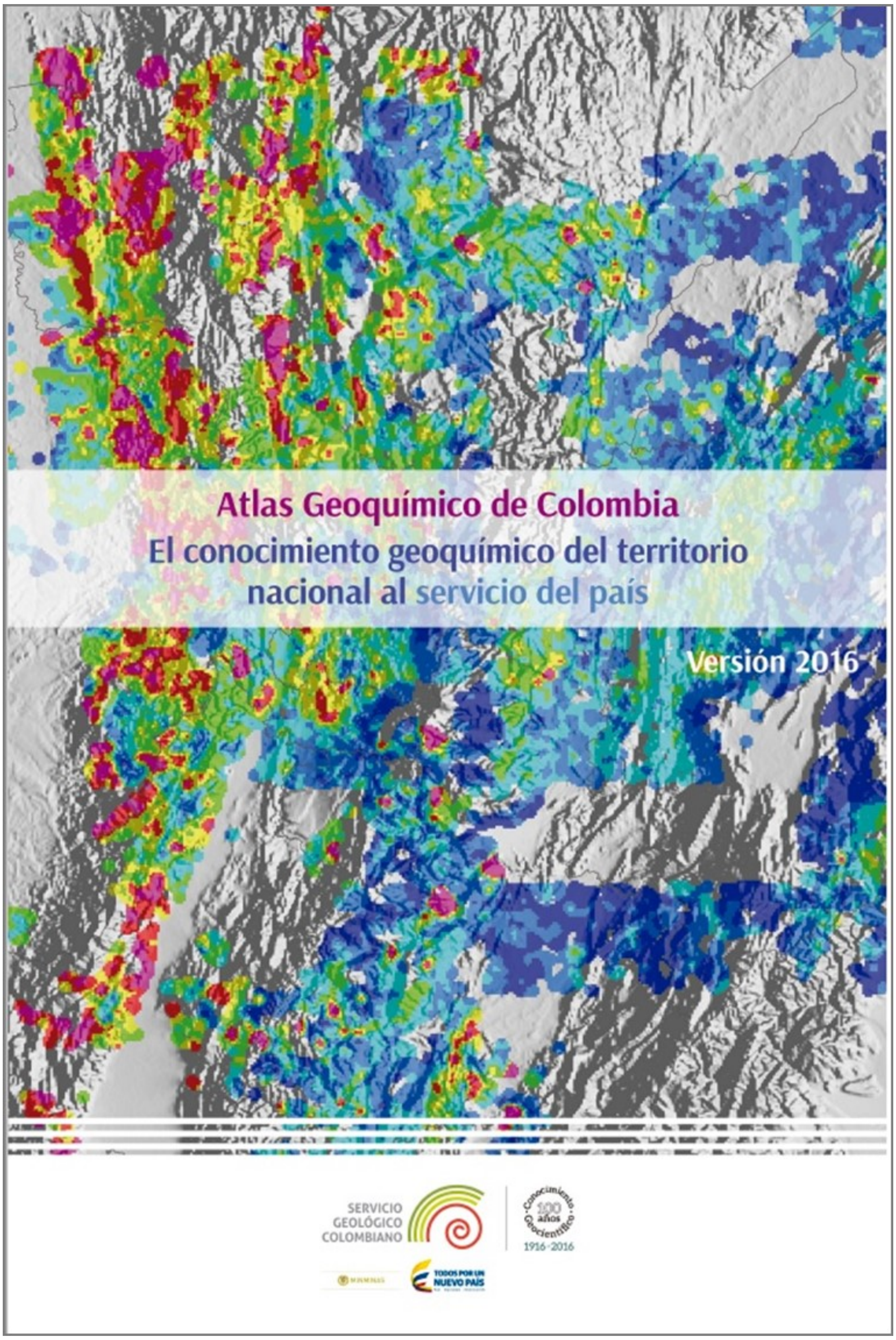


Figure 4. Front cover of the Geochemical Atlas of Colombia.

Prior to map production, the quality of the analytical data set of each element was verified then the data were subjected to statistical processing and map plotting.

The Geochemical Atlas of Colombia contains 56 geochemical maps showing the spatial distribution of the concentrations of each element and summary statistics (Figure 5). Each raster was produced by interpolation using the modified inverse distance-weighting (IDWm) algorithm of the ioGas® software.

Additionally, the Atlas comprises a second map showing the sample locations, a third map that discriminates the analytical method used, and a fourth map indicating the chemical decomposition technique (Figure 6).

These geochemical maps are used to delineate areas of interest for conducting detailed geochemical surveys for mineral resources exploration, as well as for environmental, agricultural and geomedicine studies.

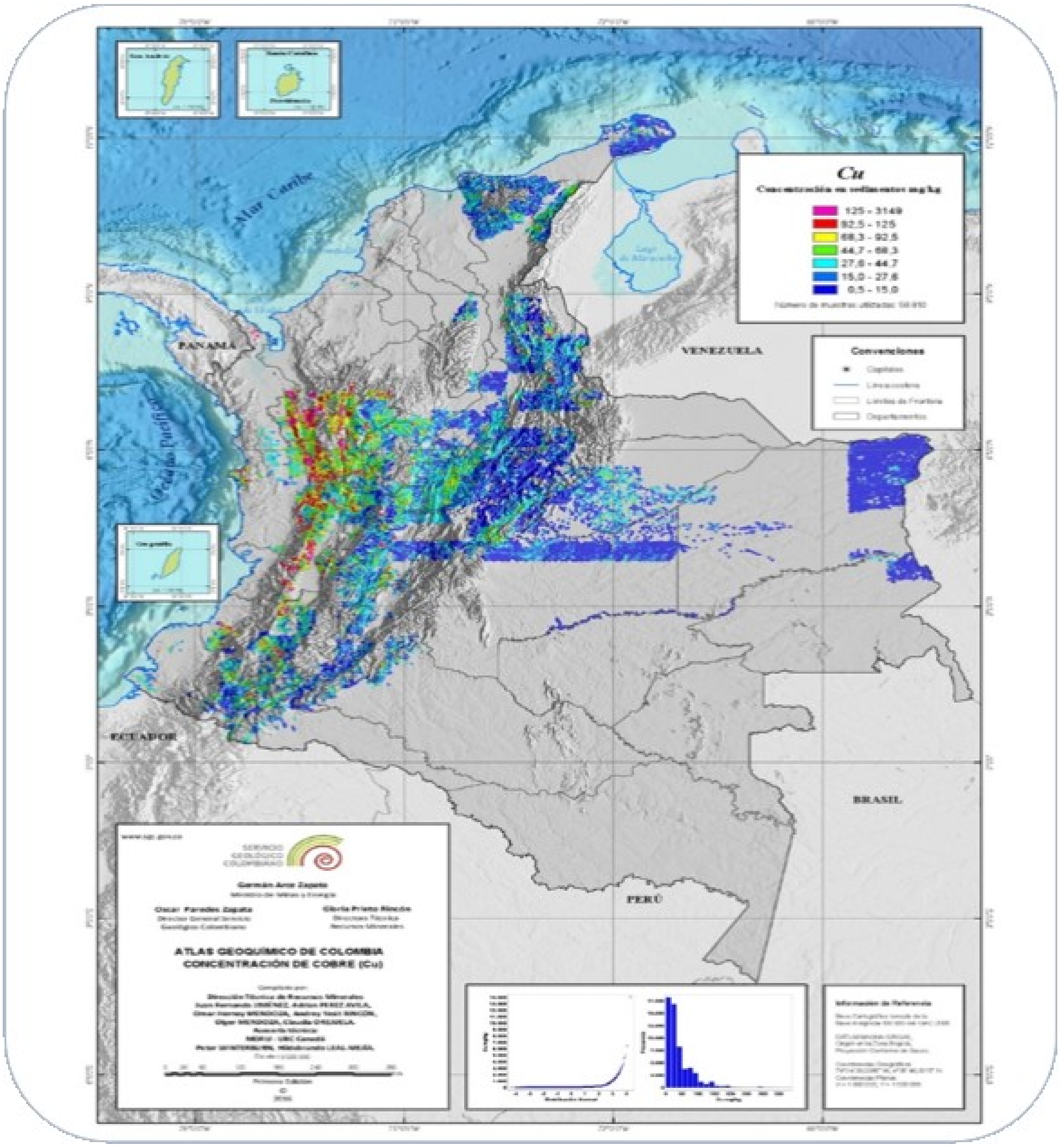


Figure 5. Geochemical distribution map of Copper included in the Geochemical Atlas of Colombia.

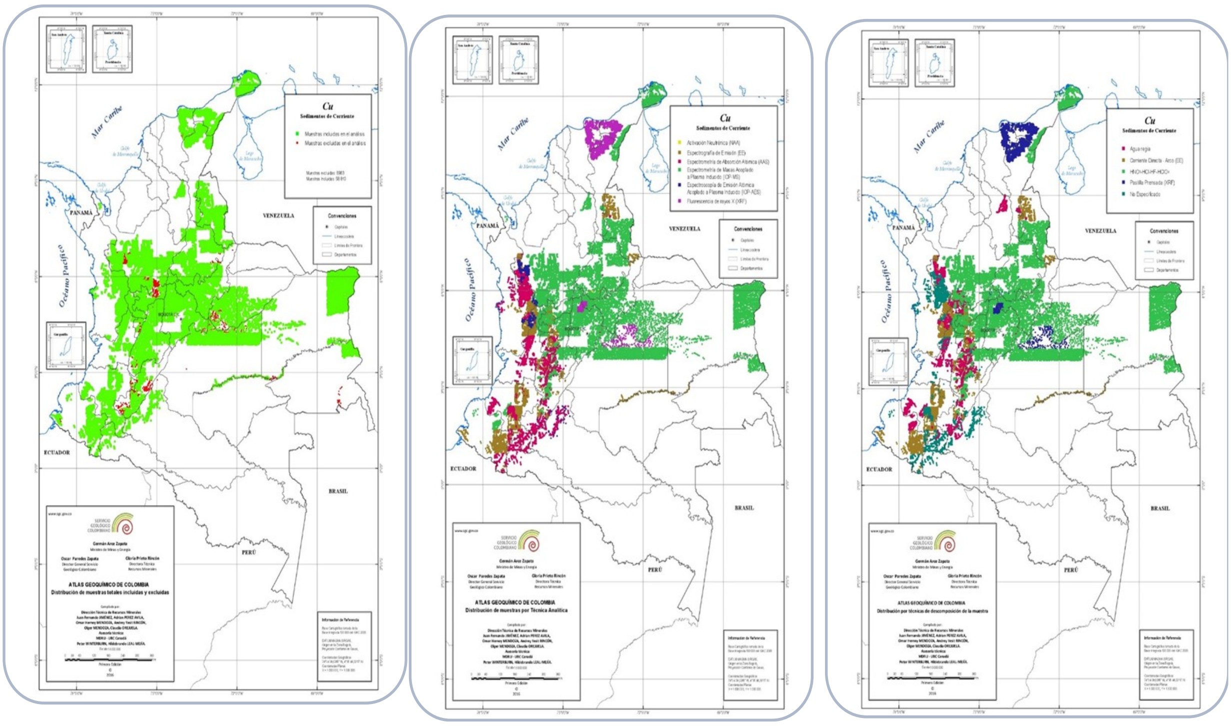


Figure 6. Set of three maps for each element included in the Geochemical Atlas of Colombia: Sample location, Analytical Method and Decomposition Technique.

Ultra-Low Density Sampling Programme

In the cooperation agreement signed between the Geological Survey of Colombia and the Geological Survey of China, a new ultra-low density sampling programme started in 2017, to cover 51 cells of 160 x 160 km (Figure 7). In 2017, 53 floodplain/overbank sediments, and 71 water samples were collected (Figure 8).

Figure 7. Map showing the ultra low-density sampling of 51 GRN grid cells of 160 x 160 km that cover Colombia.

Figure 8. Sampling of stream water and floodplain/overbank sediments.

National Geochemical studies

In 2017, during the regional geochemical studies 624 rocks, 24 panned concentrates and 871 stream sediments at a density of one sample per 3-5 km^2 were collected.

Some geochemical analyses were carried out in the geochemistry laboratories of the Geological Survey of Colombia, following standardised methodologies, and additional determinations will be performed in specialised laboratories making use of collaboration agreements. Some rocks and panned concentrates were sent for selected analyses to commercial laboratories in Canada.

In the field of medical geochemistry, new projects were initiated to investigate the levels of uranium in phosphates, mercury in coals, and arsenic in waters.

Gamma-Spectrometry Programme

In 2017, the airborne gamma-spectrometry programme (U, K, and Th), planned to survey the Andes Region and the Eastern Region of Colombia (Orinoquia – Amazonia) covered 928,677 km (Figure 9).

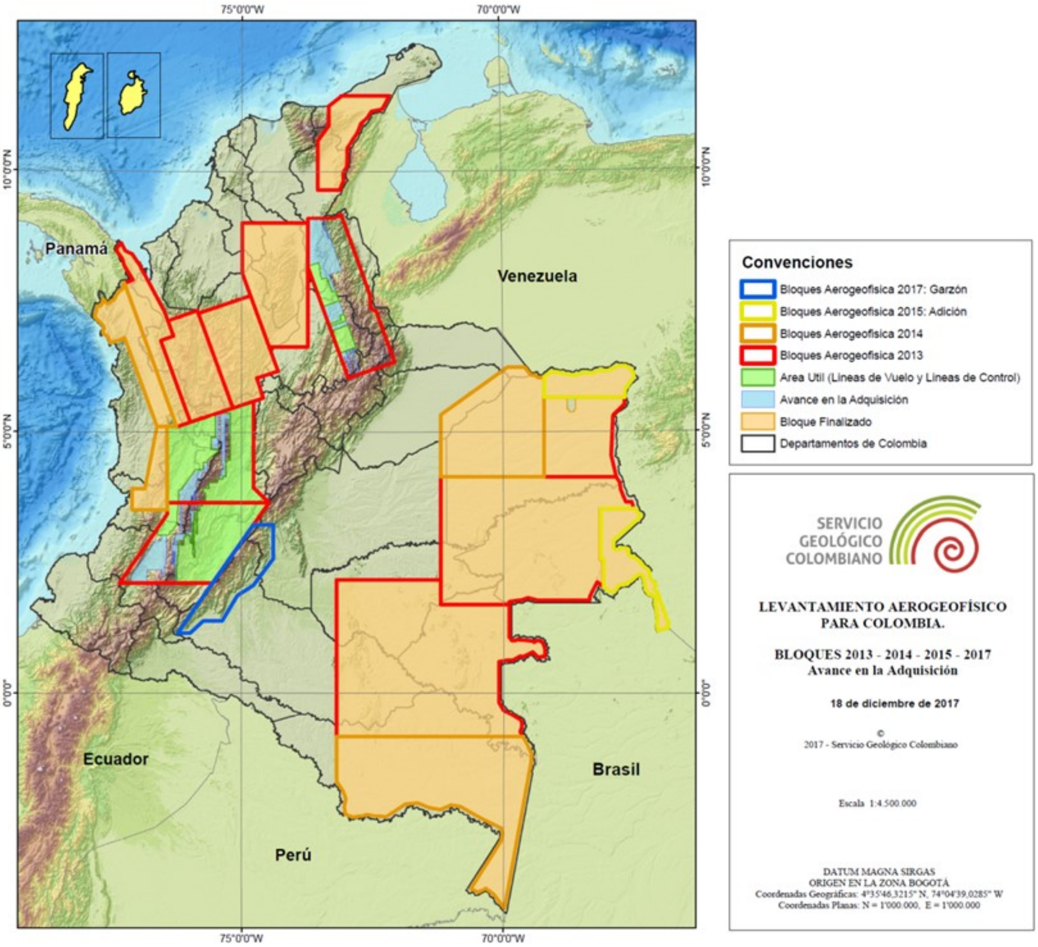


Figure 9. Map showing the progress of the gamma-spectrometry programme in Colombia (production lines each 500-1000 m; control lines each 5000-10,000 m; altitude 100-300 m). Covered areas in orange and green.

All the data produced in geochemical programmes were archived in the geodatabase EXPLORA of the Geological Survey of Colombia, which comprises geochemistry, geophysics and metallogenic information related to mineral resources of Colombia.

The Geological Survey of Colombia (SGC) will continue its geochemical programmes at different sampling densities in order to have geochemical information for its different projects.

The reports and maps produced by the Geological Survey of Colombia are available on the web page www.sgc.gov.co or by accessing the link: https://www.sgc.gov.co/sgc/mapas/Paginas/AtlasGeoquimico.aspx.

7.1.2. Africa

***AFRICA - GENERAL** (Theo Davies, University of Nigeria at Nsukka)*

For the second year running, in 2017, large-scale geochemical sampling and analyses campaigns bearing on the "Africa Geochemical Database (AGD) Project" were rather limited. Activities in this direction were largely in the form of preparatory meetings - both formal and informal - engendering plans for re-launching a well-structured geochemical database programme that would elicit wide participation from geological surveys and other geoscientific institutions around the Continent.

A concise report about the Regional Geochemical Mapping in Namibia (Figure 10) was given by Gloria Simubali at the 2017 Joint Meeting of the EGS Geochemistry Expert Group and IUGS Commission on Global Geochemical Baselines, which was held at the premises of the Geological Survey of Austria in Vienna (see Section 7.2). A second submission from Africa: *"Medical Geology Applications of an Africa Geochemical Database"* (AGD) for this Meeting by Prof. T.C. Davies (not in attendance), outlined the significance of a complete, high quality AGD for addressing the range of Earth and environmental science issues, such as mineral exploration, resource evaluation, agriculture, land use planning, processes of crustal evolution and modelling of environmental systems; and makes recommendations on the potential limitations in the compilation of such a database.

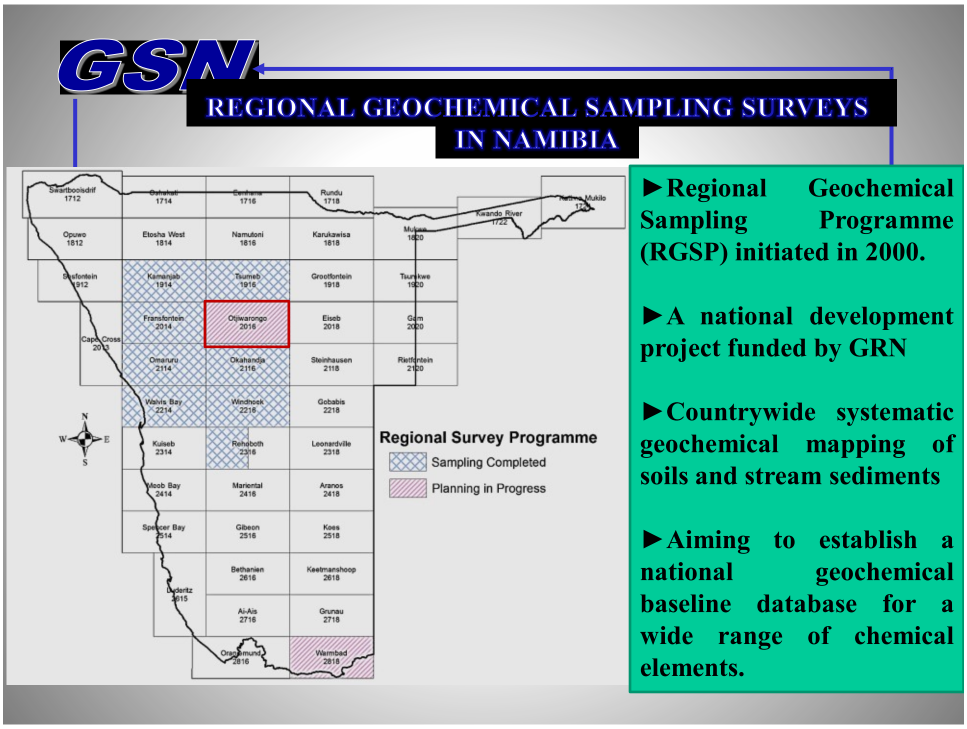


Figure 10. Namibia geochemical database. Credit: G.Simubali, Geological Survey of Namibia.

The GEO Africa geochemical baselines project proposal

During 2017, the GEO Group on Earth Observations tabled again the Project Proposal (Activity ID77): "Africa Geochemical Baselines" for support by EuroGeoSurveys, IUGS Commission on Global Geochemical Baselines and other institutions. This Project aims *'To develop a land base multi-element geochemical baseline database for mineral resource and environmental management'*, and describes a work programme for the period 2017-2019. The project proposal is within the vision of GEO: *'To realise a future wherein decisions and actions, for the benefit of humankind, are informed by coordinated, comprehensive, and sustained Earth observations and information'*. However, at the August 2017 Skype discussion, it became obvious that the GEO Group on Earth Observations is not a funding platform, and the funding should be found from other sources. However, as the project proposal is important for Africa, the following excerpts are worth reporting, and were copied from the website (https://www.earthobservations.org/activity.php?id=77).

Planned Activities for the period 2017-2019

- Capacity building: Organisation of capacity-building workshops in global geochemical baseline mapping at central locations in Northern, Eastern, Southern, Western and Central Africa. The workshops will comprise indoor lectures in applied geochemistry, including data processing and map plotting, and training in the field (selection of sampling sites, and sampling);

- User involvement: Participation of applied geochemists from all African countries;
- Geographical coverage: The whole African continent.

Sampling and Analyses

GEO's objective is: *'To develop a geochemical baseline database for the entire African continent through systematic sampling and chemical analysis according to the specifications of IGCP 259 International Geochemical Mapping (Darnley et al., 1995)'*.

It is proposed to use only one sample medium, depending on terrain type, namely overbank or floodplain or catchment basin sediment, which is generally alluvial (or agricultural soil).

The framework for the sampling is the Global Geochemical Reference Network (GRN), shown in Figure 11, established by IGCP 259 (Darnley et al., 1995). The GRN consists of about 5000 grid cells, each approximately 160 x 160 km in size (area 25,600 km^2). The 54 countries in Africa are covered by approximately 1500 GRN grid cells (see Figure 11). Five random sites are identified within each cell for a total of 7500 sample sites for the whole Continent (approximately 1 site per 4000 km^2).

Sample media:

- Overbank sediment (alluvial soil) in mountainous and hilly terrains, and
- Floodplain or catchment basin sediment (alluvial soil) in desert, savannah, and plain terrains.

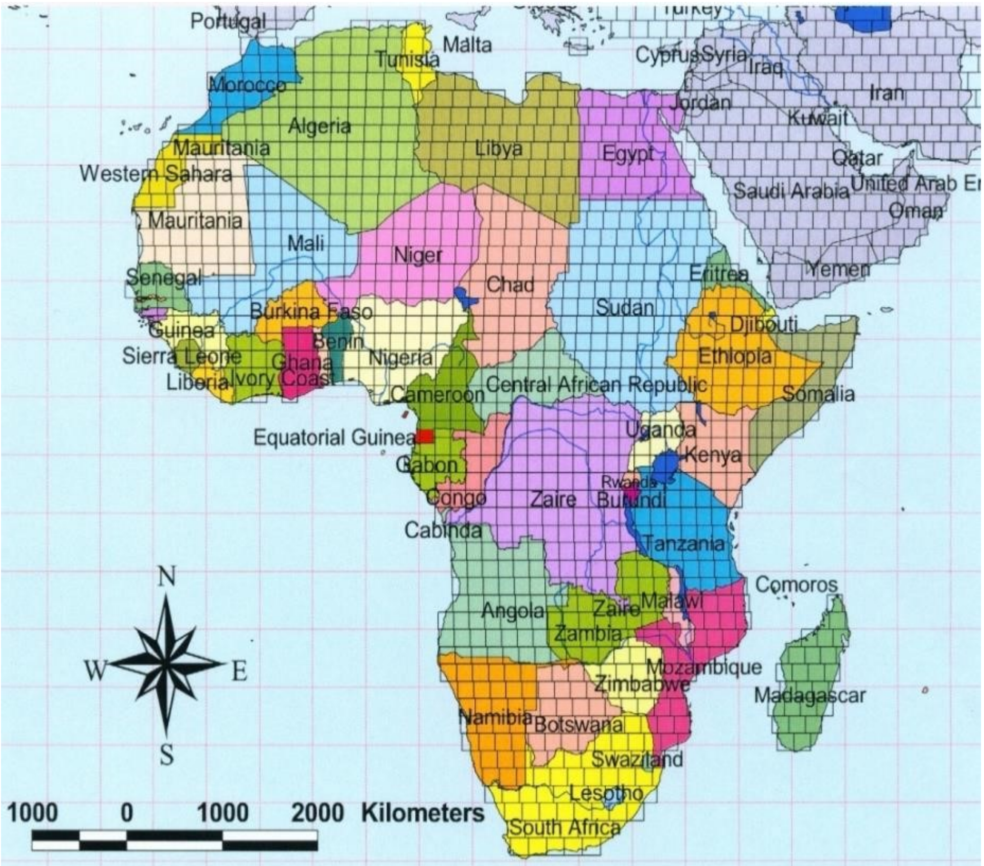


Figure 11. The GRN cells in Africa.

At each site, two samples will be collected, a top and a bottom sample. The top (surface) sample will be collected from 0-25 cm, and the bottom (deeper) 25-cm thick sample below a depth of 75 cm, and always from single horizons; if the thickness of the sampled horizons is less than the specified thickness, then the thinner horizon shall be sampled. The total number of samples will be in the order of 15,000. Duplicate field samples will be collected from at least 3 per cent of the sampling sites, giving a total of 225 duplicated field sites, and 450 samples.

The samples, after preparation at a central facility in Africa, will be analysed for 76 elements at the laboratories of the China Geological Survey (UNESCO International Research Centre on Global-Scale Geochemistry). Splits of each sample will be archived and stored for future investigations either at a central facility within Africa or at a facility designated by each participating African country.

To monitor the quality of geochemical data, five large standard samples with different element concentrations (low to high) will be prepared.

The cost of sampling and sample preparation for the whole African continent, and preparation of the five standard samples, is approximately in the order of 5 million Euros.

The cost of laboratory chemical analysis for 76 elements is approximately 3 million Euros, which may be funded by China.

UNESCO Chair of Medical Geology in Africa

In connection with identification of a central facility in Africa (referred to in the GEO Proposal above) for sample preparation and partial analyses of the samples, it is noteworthy that a pre-proposal for the establishment of a UNESCO Chair of Medical Geology at the University of Nigeria at Nsukka (UNN) has been put forward to the UNESCO Regional Representation (Abuja Office). The Geology Department at UNN, identified as the likely home of the proposed Chair, has recently moved into extensive new buildings in the Austin Avuru Complex, equipped with modern analytical facilities, and has secured tentative approval by the Alexander von Humboldt Foundation of Germany for the provision of equipment subsidy towards the acquisition of a modern ICP-MS Unit.

Informal Meetings on the Nigeria Geochemical Database (NGD)

Informal meetings on the NGD were held at the Department of Geology, UNN in November 2017, and was attended by the Director of the Nigeria Geological Survey Agency (NGSA), Mr. Isaac Okorie, who is also in charge of the Kaduna Geochemistry Laboratory in Nigeria; the Head of the Department of Geology, UNN, Dr. Solomon Onwuka, the Office Manager of EuroGeoSurveys Ms. Céline Andrien and Prof. T.C. Davies.

Among the topics discussed at these meetings were the collection and analyses of samples from additional cells in the GRN of Nigeria, and the role of a revamped Kaduna Geochemistry Laboratory as a central facility for the preparation and partial analyses of samples taken from the Nigeria GRN cells in future regional geochemical surveys.

7.1.3. Asia

***CHINA AND OTHER ASIAN COUNTRIES* (Xueqiu Wang, IGGE)**

Extent of national/regional/global support from sources other than IUGS and IAGC

In 2017, the China Government provided funding of approximately 3,200,000 US$ for the Mapping Chemical Earth Programme: Global Geochemical Mapping Project in cooperation with 12 countries.

China Geochemical Baselines Projects

The China Geochemical Baselines Project (CGB) is a contribution to the work of IUGS Commission on Global Geochemical Baselines. Its purpose is to document China's nationwide geochemical baselines on the spatial distribution and evolution of inorganic chemical elements. Each Global Reference Network (GRN) cell of 160 x 160 km is divided into four 80 x 80 km cells (CGB). Approximately 1,500 CGB cells cover the whole area of China (9.6 million km^2). Soil samples for pedosphere and rock samples for lithosphere geochemical baselines were collected in each cell. At two sampling sites, samples of soil/overbank/floodplain sediments from each CGB cell were collected. At each site, two depth related samples were taken: 0-25 cm and >100 cm. Representative rock samples from different geological units were concurrently collected in each CGB cell to interpret the geogenic sources of secondary geochemical patterns, and to study the evolution of elements with geological time from Archaeozoic to Quaternary.

A one-year pilot study was conducted in 2008 to test and refine the recommended protocols, and to optimise field logistics for the geochemical sampling. Subsequently, a 5-year period, from 2008 to 2012, was planned to cover the whole of China's mainland, and a 2-year extension from 2013-2014 was devoted to data interpretation and publications. In total, 6617 soil/catchment sediment samples from 3382 sites were collected from 1500 CGB grid cells across the whole of China (9.6 million km^2), corresponding to a density of approximately one sample site per 3000 km^2. In addition, 11,943 rock samples were collected to aid the interpretation of geogenic sources of elements. After being air-dried and homogenised, each raw sample of 5000 g is split into two sub-samples, one of 2000 g by sieving to <10 mesh (<2 mm) for laboratory analysis and the other of 3000 g for storage and future investigation. A 1000 g sieved sample of soil and sediment was ground to <74 μm (200 mesh) in an agate or pure-aluminium-porcelain mill. A 500 g ground sample was sent to the laboratory for analysis. The remaining sample was bottled and archived. Seventy-six chemical elements plus five additional chemical parameters of Fe^{2+}, Organic C, CO_2, H_2O^+ and pH) were determined under strict laboratory analytical quality control.

Internet-based software named Digital Chemical Earth, similar to Google Earth, was developed to manage the geochemical database and to allow access to the vast amount of geochemical data and maps through the Internet.

Initial results show an excellent correlation of element distribution with lithology, mineral resources and mining activities, industry and urban activities, agriculture, and climate. These results were presented at the 34th IGC in Australia in August 2012, the 26th IAGS in New Zealand in November 2013, and the 27th IAGS in the USA in April 2015, and some results published in the Journal of Geochemical Exploration (Wang et al., 2015). A data set consisting of 40 elements was released through the website of the UNESCO International Centre on Global-Scale Geochemistry in 2017 (http://globalgeochemistry.com).

The second round of sampling started in 2016, and by the end of 2017, a total of 1200 locations were sampled.

China International Cooperation Programme on Global Geochemical Baselines Mapping

Since 2016, China Government through China Geological Survey and the Ministry of Land and Resources sponsored the UNESCO International Centre on Global-Scale Geochemistry for the Mapping Chemical Earth Programme: Global Geochemical Mapping Project. All the international cooperation projects sponsored by China Government were incorporated into this programme, which is opened to all countries that like to cooperate with China for global-scale geochemical mapping. In 2016 and 2017, China has cooperated with Laos, Cambodia, Mongolia, Russia, Iran, Turkey, Papua New Guinea, Indonesia, Tanzania, Eritrea, Madagascar, and Mexico.

- Laos: A total of 146 global-scale soil/catchment sediment samples from 73 sites were collected in 2014 and 2015 across the whole of Laos (~ 200,000 km^2) corresponding to a density of approximately one sample site per 3000 km^2. A total of 76 elements were determined in 2016 and the geochemical baselines atlas was produced in 2017.
- Mongolia: A total of 660 catchment sediment samples from 330 locations were collected in 2016 and 2017 across the whole of Mongolia corresponding to a density of approximately one sample site per 3000 km^2. A total of 76 elements were determined in 2017 and the geochemical baselines atlas will be produced in 2018.
- Cambodia: A total of 32 catchment sediment samples from 16 locations were collected in 2016 and 2017 across the whole of Cambodia. A total of 76 elements will be determined in 2018.
- Indonesia: A total of 32 catchment sediment samples from 16 locations were collected in 2017. A total of 76 elements will be determined in 2018.
- Eritrea: A total of 24 catchment sediment samples were collected in 2017. It is expected to complete the sampling over the whole country in 2018.
- Tanzania: A total of 850 catchment sediment samples were collected in 2016 and 2017. It is expected to complete the sampling over the whole country in 2018.
- Iran: A total of 1000 catchment sediment samples were collected from 500 locations in 2017. It is expected to complete the sampling over the whole country in 2018.

China Data Release

Two Chinese continental-scale geochemical databases were released in 2017:

- The *"Environmental Geochemical Monitoring Networks (EGMON) project"* (http://www.globalgeochemistry.com/en/main.php?action=displaybody&s=107&pid=136)
- 40 Elements of the *"China Geochemical Baselines Project"* (http://www.globalgeochemistry.com/en/main.php?action=displaybody&s=107&pid=144)

'Chemical Earth', the first ICGG Newsletter

'Chemical Earth' is the first Newsletter of the UNESCO International Centre on Global-Scale Geochemistry (ICGG), which was circulated in December 2017, and is available for download at http://www.globalgeochemistry.com/en/main.php?action=displaybody&s=107&pid=157. It includes the speeches of people that were delivered at the opening ceremony of the ICGG on 12 May 2016, and a historical outline of the global geochemical baselines project leading to the establishment of the ICGG in Langfang.

7.1.4. Australasia

AUSTRALIA (Patrice de Caritat, Evgeniy Bastrakov, Geoscience Australia; Paul Morris, GSWA)

2017 saw the release of further publications on the National Geochemical Survey of Australia (NGSA) dataset, including statistical and compositional analysis of the data. Maps of the background geochemical compositions for 59 elements analysed by Aqua Regia were published (Science of the Total Environment; see Section 6.1). A paper on upscaling mineral prospectivity results obtained at the regional scale, in the southern Thomson region (northern New South Wales and southern Queensland), to the continental scale, was published in the Australian Journal of Earth Sciences (see Section 6.1).

Presentations of NGSA data and interpretations were made at the Critical Zone Science Conference (Arlington, VA), the European Geosciences Union (EGU) General Assembly (Vienna), the7th International Workshop on Compositional Data Analysis (Sienna), the Goldschmidt Conference (Paris), the 18th Annual Conference of the International Association for Mathematical Geosciences (Fremantle, WA), and Exploration '17 (Toronto) (see Section 6.2).

Importantly, the NGSA was the motivation behind starting a new, higher density geochemical survey over parts of northern Australia, the Northern Australian Geochemical Survey (NAGS), under the Australian Government's *'Exploring for the Future'* (2016-2020; EFTF) programme (http://www.ga.gov.au/eftf). NAGS aims to advance methods and approaches originally developed by the NGSA (Caritat and Cooper, 2011) to systematically characterise the chemical nature of Australian regolith and the processes that control its composition. NAGS will provide a basis for informed decision making about regional land use, agriculture, and mineral and energy resource potential. Similar to NGSA, the NAGS project is targeting overbank/floodplain sediments at the downstream end of large hydrographic catchments. During 2017 Geoscience Australia in collaboration with the geological surveys of Northern Territory and Queensland coordinated sampling of 780 sites in the EFTF focus area between Tennant Creek and Mt Isa in the Northern Territory and Queensland (Figure 12). The average sampling density was one sample per ~500 km^2. The sample collection followed an abbreviated version of the NGSA sampling protocol, collecting the top 0-10 cm of the profile. To extract the maximum amount of geochemical information, the samples are currently being analysed for more than 60 elements using state-of-the-art analytical techniques. Subsequent follow-up surveys and potentially a completion of the NGSA coverage (which couldn't gain access to a large area in northwestern Australia) may occur over the next three years (2018 to 2020). Geochemical data and metadata will be released on an ongoing basis on Geoscience Australia's website (http://www.ga.gov.au/).

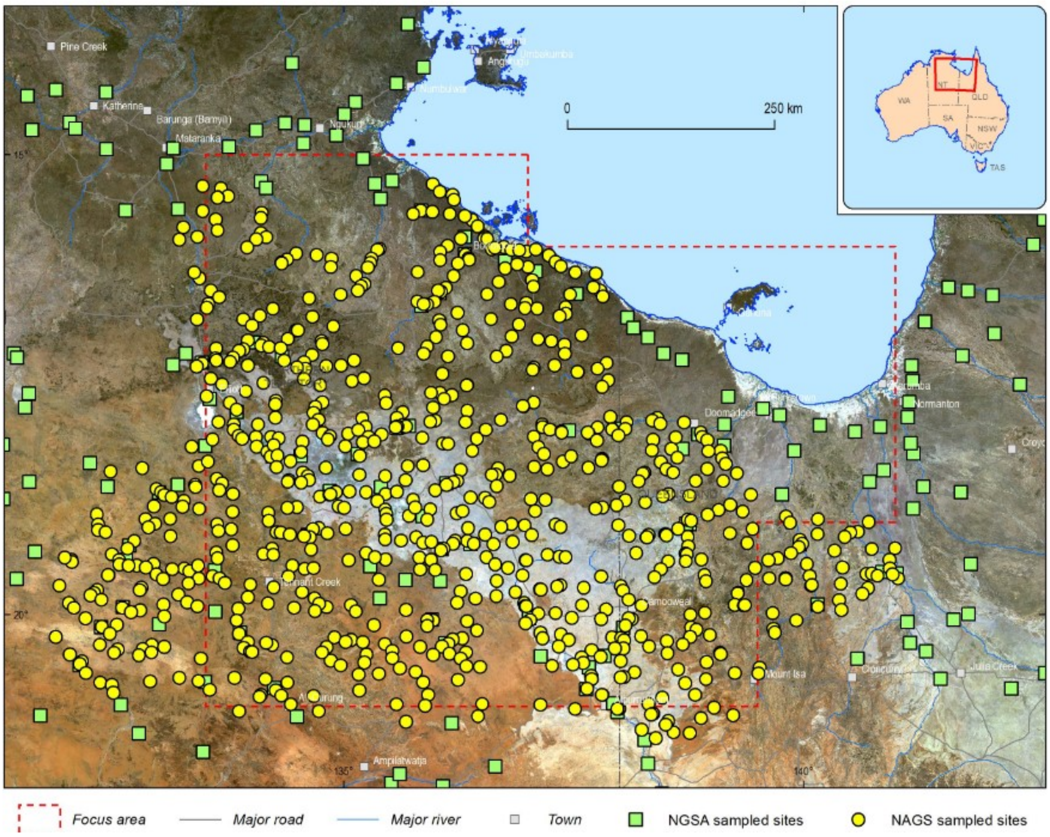


Figure 12. NAGS stage 1 sampling sites area relative to the EFTF focus area (red dashed box).

The Geological Survey of Western Australia's (GSWA) continued to prepare and release reports on various geochemical surveys. The abstract book from their annual prospectivity promotion conference contains some of these studies (see Section 6.1).

NEW ZEALAND ***(Adam Martin, GNS Science)***

Seven new regional or urban geochemical soil surveys were undertaken or completed in New Zealand in 2017. As part of an ongoing NZ$ 8M investment programme in new geoscience data, New Zealand Petroleum & Minerals (NZP&M) commissioned GNS Science to undertake six soil geochemical baseline surveys in the South Island of New Zealand (Figure 13), in 2017. Additionally, GNS Science completed a systematic soil geochemical baseline survey of Dunedin City (Figure 13) in 2017. These surveys were undertaken at a variety of scales (1 km, 2 km, 4 km and 8 km) with samples collected from three depths (0-2 cm; 2-18 cm; 50-70 cm) in each survey. More than 1300 sites and 3000 samples have now been analysed for their chemical element composition in New Zealand, supported by rigorous quality control procedures. The results of these surveys are being made available online (pet.gns.cri.nz) and the interpretation of these data were communicated through a number of publications and conferences in 2017 (see Sections 6.1, 6.2).

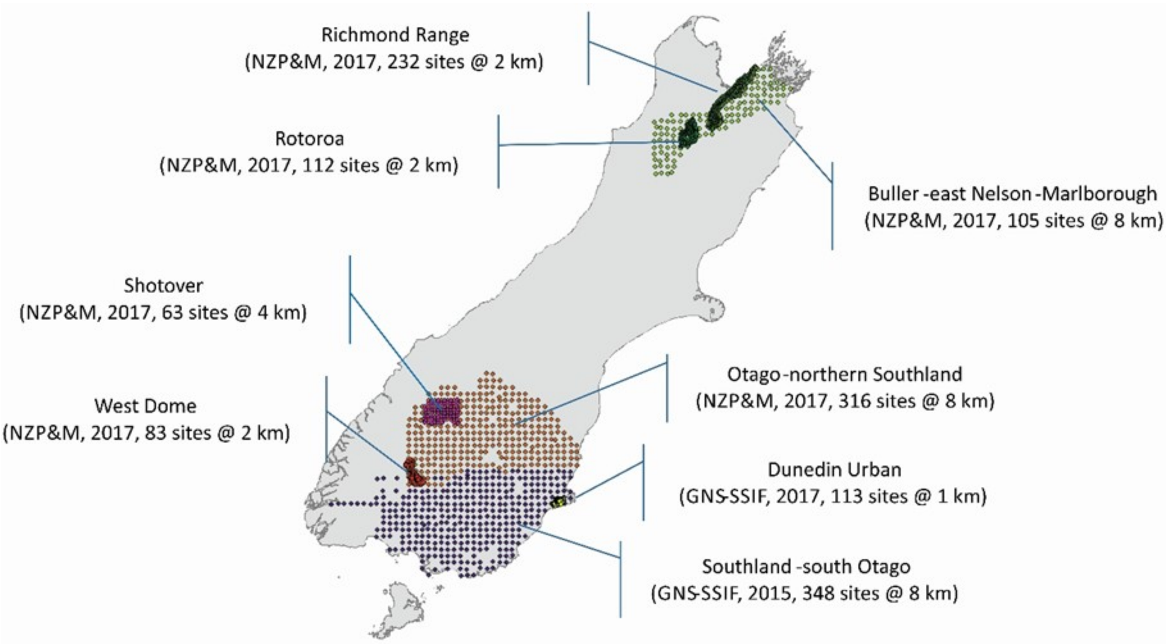


Figure 13. The location of the seven new soil geochemical baseline surveys in New Zealand, as well as the existing Southland-south Otago survey.

7.1.5. Europe

EUROPE ***(Clemens Reimann, Geological Survey of Norway)***

The two volumes of the FOREGS-EGS Geochemical Atlas of Europe (Salminen et al., 2005; De Vos et al., 2006), available for free download from weppi.gtk.fi/publ/foregsatlas/, are still very popular. The complete European database of all field and geochemical data collected as part of this project and the related digital photo archive are also freely available at this website. The data of widest interest are the stream water data, since this is the only harmonised dataset in Europe and complies to the specifications of the Directive on Infrastructure for Spatial Information in the European Community (INSPIRE), and to the Water Framework Directive 2000/60/EC.

The EGS Geochemistry Expert Group published in April 2014 a two-volume set of the GEMAS project (GEochemical Mapping of Agricultural and Grazing land Soil) entitled

"*Chemistry of Europe's Agricultural Soils*" at density of 1 sample site/2500 km^2. This was a cooperation project with industry, and was partly funded by the European Association of Metals (Eurometaux) for the provision of harmonised data compliant to the European Commission's REACH Regulation (Registration, Evaluation and Authorisation of Chemicals).

New activities during 2017 included the writing of papers on different aspects of the GEMAS project (see Section 6.1). The new analytical data of total C, N and S, and magnetic properties on agricultural soil samples, and soil colour on dry and moist samples on both agricultural and grazing land soils have been compiled, and their quality is in the process of assessment. The determination of Sr isotopes on agricultural soil samples is still ongoing.

7.2. Public Relations Accomplishments

The main priority of the Public Relations and Finance committee is to promote the project for the purpose of attracting sponsors that may be interested to finance the Global Geochemical Baselines project in different parts of the World.

7.2.1. Joint meeting of the EuroGeoSurveys Geochemistry Expert Group and IUGS Commission on Global Geochemical Baselines

The joint annual meeting was hosted by the Geological Survey of Austria (GBA) at its premises in Vienna on the 20 and 21 April 2017. As the EuroGeoSurveys Geochemistry Expert Group (EGS-GEG) is the most active in applied geochemistry, it was decided that a joint meeting with the IUGS Commission on Global Geochemical Baselines (IUGS-CGGB) was beneficial. This particular year was also important, because EGS-GEG was celebrating its 30th anniversary and IUGS-CGGB its 20th anniversary. In total, 37 people attended the meeting from Africa, Asia, Australia, Europe, and South America (Figure 14). This was the second time with such a large attendance after the Athens October 2000 joint meeting.

LIST of PARTICIPANTS

1. Clemens Reimann, (Chair, Norway)
2. Philippe Négrel (Deputy Chair, France)
3. Edith Haslinger (Austria)
4. Gerhard Hobiger (Austria)
5. Albert Schedl (Austria)
6. Fiona Fordyce (United Kingdom)
7. Alejandro Bel-lan (Spain)
8. Timo Tarvainen (Finland)
9. George Morris (Sweden)
10. Jasper Griffioen (The Netherlands)
11. Mateja Gosar (Slovenia)
12. Michal Poňavič (Czech Republic)
13. Sophie Decree (Belgium)
14. Christian Burlet (Belgium)
15. Maria Joao Batista (Portugal)
16. Vibeke Ernstsen (Denmark)
17. Karl Fabian (Norway)
18. Daniela Mackovych (Slovakia)
19. Igor Slaninka (Slovakia)
20. Aleksandra Gulan (Serbia)
21. Daniella Tolmács (Hungary)
22. Gyozo Jordan (Hungary)
23. Katalin Szabo (Hungary)
24. Adam Kovacs (International Commission for the Protection of the Danube River, Hungary)
25. Alecos Demetriades (IUGS-CGGB)
26. Chaosheng Zhang (Ireland)
27. Benedetto De Vivo (Italy)
28. Annamaria Lima (Italy)
29. Stefano Albanese (Italy)
30. Daniela Zuzolo (Italy)
31. Jurian Hoogewerff (Australia)
32. Raimon Tolosana-Delgado (Germany)
33. Gloria Simubali (Namibia)
34. Xueqiu Wang (China - ICGG)
35. Juan Pablo Lacassie Reyes (Chile)
36. Igor G. Spiridonov (Russia)
37. Alexander A. Kremenetsky (Russia)

LIST of PARTICIPANTS

Figure 14. Group photograph of meeting participants.

The Director of GBA, Mr. Peter Seifert, opened the meeting. Clemens Reimann (Chairperson of EGS-GEG) chaired the two-day meeting, and started by thanking all attendees for their participation and wished that the EGS-GEG be as open in the future, as it is now, because this proved to be its strength. Alecos Demetriades stressed the importance of the joint meeting of the EGS-GEG and IUGS-CGGB, especially for members from different continents, as the aim is to establish similar Working Groups in all continents.

Apart from the business meeting, where all on-going work was discussed, there were 22 twenty-minute presentations, which made the meeting much more interesting, because on-going work was presented and discussed, either during the meeting or at coffee breaks, lunch and the evening shared meals. The titles of the 22 presentations, and the names of presenters, are given below:

1. Accomplishments during 30 years Geochemistry Expert Group (Alecos Demetriades)
2. Annual report to EuroGeoSurveys National Delegates meeting (Clemens Reimann)
3. Fighting hazardous substances pollution in the Danube River Basin: challenges and opportunities (Adam Kovacs ICPDR)
4. Simona Project sediment quality monitoring in the Danube with ICPDR (Gyozo Jordan)
5. IUGS Commission on Global Geochemical Baselines and its relationship with the UNESCO International Centre on Global-Scale Geochemistry (Alecos Demetriades)
6. Introduction to the UNESCO International Centre on Global-Scale Geochemistry (ICGG) and the Mapping Chemical Earth Programme (Xueqiu Wang)
7. Spatial analysis of Ni by using digital image processing techniques on the GEMAS project's agricultural soil data (Gyozo Jordan)
8. Sr isotopes – results so far and a presentation and discussion of *"Chances for regional geochemistry in Forensic Geochemistry"*: Strontium isotope results on GEMAS Ap samples and forensic applications (Jurian Hoogewerff)

9. Spatial analysis in geochemistry at regional, field and micro scales: New opportunities and challenges (Chaosheng Zhang)
10. Surveying the Geochemical Quality of the UK Surface Environment: The G-BASE Programme (Fiona Fordyce)
11. Applied Geochemistry at SGU 2016-2017 (George Morris)
12. First results of environmental monitoring of Campania Region (Benedetto De Vivo)
13. Applicability of portable XRF in baseline geochemical mapping (Timo Tarvainen)
14. Prague URGE results (Michal Poňavič)
15. Improving soil geochemical mapping through laser-enhanced spectroscopy (Christian Burlet)
16. Soil geochemistry in exploration in the Portuguese Iberian Pyrite Belt: A historical perspective (Maria Joao Batista)
17. Geochemical Programme of Chile (Juan Pablo Lacassie Reyes)
18. Current state of geochemical mapping of the territory of Russia (Igor G. Spiridonov and Alexander A. Kremenetsky)
19. Basic information about European transnational funding possibilities in the field of geochemistry (Heinz Buschmann):
    - INTERREG: Alpine Space (www.alpine-space.eu/)
    - COST Action (http://www.cost.eu/participate/open_call)
20. Regional geochemical mapping in Namibia (Gloria Simubali).
21. Methane geochemistry in The Netherlands: Natural occurrence and a historical blow-out site (Jasper Griffioen)
22. About the limitations of compositional data and how might be overcome in geochemical data analysis (Raimon Tolosana Delgado)

7.2.2. Short Training Course on the use of Geochemical Software for Geochemical Map Generation, 23-25 April 2017, Laos

In total, 23 participants attended the course (Figure 15). Ms. Wang Wei (UNESCO-ICGG) used the Laos geochemical data set as an example to teach the participants the handling of Geoexpl Software (international version) for geochemical map plotting.

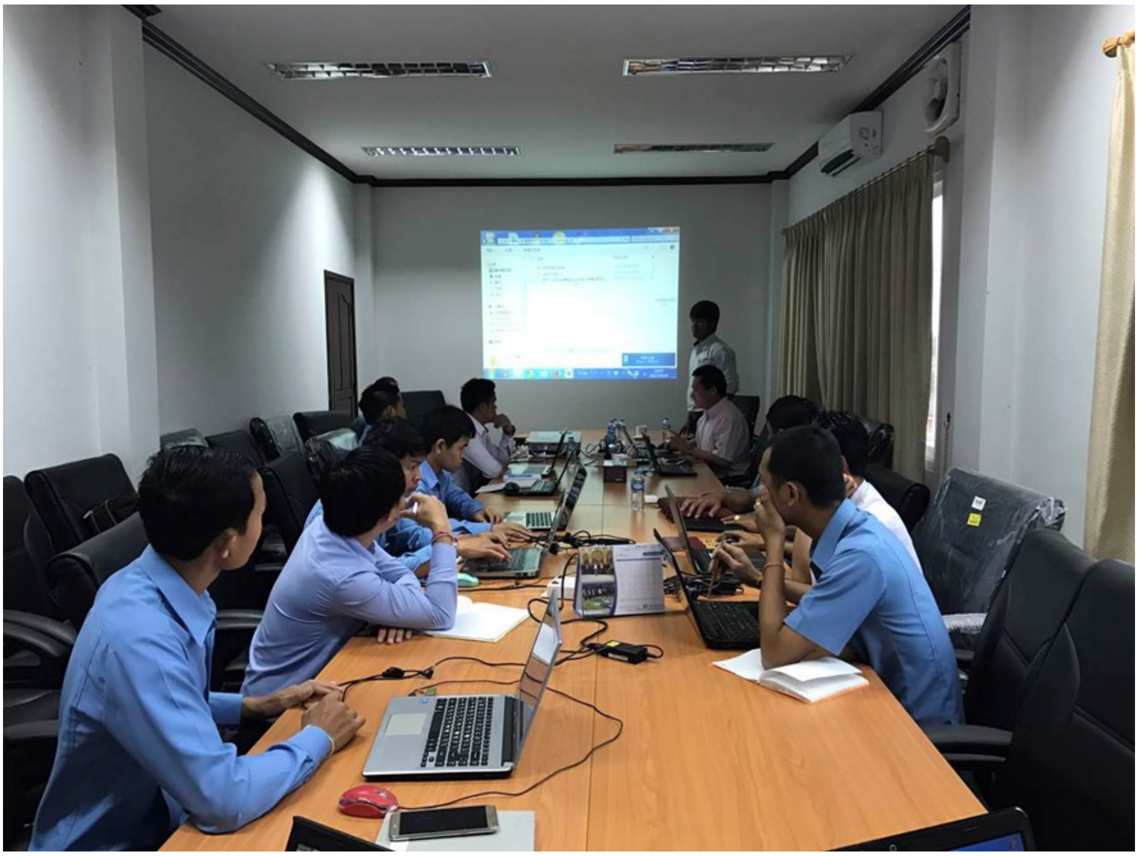


Figure 15. Participants in the geochemical software training course in Laos.

7.2.4. 4th YES Congress on Mitigating Geohazards and Resources for Future Generations, Geological Survey of Iran, Tehran, Iran, 27-30 August 2017

The IUGS-CGGB at the request of the YES Network organised in collaboration with the Geological Survey of Iran (GSI) a two-day workshop on "Global Geochemical Mapping". For the organisation of the Workshop Alecos Demetriades (IUGS-CGGB) was in contact with geoscientists of the Geological Survey of Iran, Bita Mirzapour and Marziyeh Esterabi Ashtiani for the lectures, and Hooman Dada Shzadeh Ahari for the field training. The expenses for the hiring of the coach, and packed lunches and soft drinks were sponsored by the IUGS-CGGB.

The field-training sample sites were mainly discussed with Ali Najafi (GSI International Projects Director), and Hooman Dada Shzadeh Ahari, who organised on Monday 28 August 2017, a pre-field training course visit to the drainage basin in the Jajrud area, which is 25 km to the ENE of Tehran. It is a third order river valley, where only floodplain sediment should be collected according to the field sampling guidelines (Darnley et al., 1995; Salminen, Tarvainen et al., 1998). However, as the second order stream could not be reached by coach, suitable sites were located for stream and floodplain sediment, and at the request of GSI geoscientists agricultural and grazing land soil (see Figure 16). Even old terraces were observed on the west bank of the river, because the river is very active, downcutting its valley. No suitable residual soil sites were located in this particular stretch of the river basin.

Figure 16. Google Earth photograph showing the stream sediment, floodplain sediment and agricultural soil sample sites, and possible grassland site for the grazing land soil, Jajrud, Iran.

Discussion: During the road trip, the MoU signed between GSI and China Geological Survey was discussed with Ali Najafi (GSI International Projects Director), who stated that there was disagreement with Xueqiu Wang (Executive Director of the UNESCO International Centre on Global-Scale Geochemistry) with respect to compositing the individual samples collected in each Global Terrestrial Network of 160 x 160 km to make an artificial laboratory sample. He informed Xueqiu Wang that all samples would be analysed at the GSI laboratory.

Tuesday 29 August 2017: Lectures

The first day of the workshop was devoted to lectures, delivered mainly by Alecos Demetriades (IUGS-CGGB), and one lecture by Zhou Jian (Geochemist of the Institute of Geophysical and Geochemical Exploration (IGGE) and the UNESCO International Centre on Global-Scale Geochemistry). The titles of the lectures were:

1. Introduction to Applied Geochemistry (including Exploration Geochemistry) by Alecos Demetriades

2. Sampling and sampling designs (stream sediment, soil, overbank sediment and rock for mineral exploration, including environmental geochemistry surveys) by Alecos Demetriades

3. Sample preparation, sample randomisation, insertion of control samples and submission to laboratory by Alecos Demetriades

4. FOREGS laboratory scheme (Forum of European Geological Surveys: Geochemical Atlas of Europe) by Alecos Demetriades

5. Quality control scheme (Independent Quality Control, and elaboration of different statistical techniques for data validation) by Alecos Demetriades

6. Statistical-geostatistical data treatment – Data processing by graphical methods – Geochemical background, threshold and anomalies by Alecos Demetriades

7. Silk Road geochemical mapping by Zhou Jian
8. Application of Geochemical Mapping for Mineral Exploration and Environmental Assessment by Alecos Demetriades

The lectures started at 09:00 and finished at about 18:15. In total, 48 people attended the workshop lectures. To each attendee the 2nd version of the Arthur Darnley DVD was given.

Wednesday 30 August 2017: Demonstration of field sampling methods

Before boarding the coach, it was pointed out to all field trip participants to use the knowledge given to them during the lecture on sampling to locate suitable sites for stream and floodplain sediment, agricultural and grazing land soil. In total, 37 people participated in the field-training workshop (Figure 17).

Figure 17. Group photographs of field training workshop participants, Jajrud, Iran.

Stream sediment sampling

To begin with, it was stressed that in global geochemical mapping stream sediment is collected from second and not third order streams. As the coach could not reach a second order stream, the stream sediment sampling procedure was going to be demonstrated at a suitable site of the third order stream.

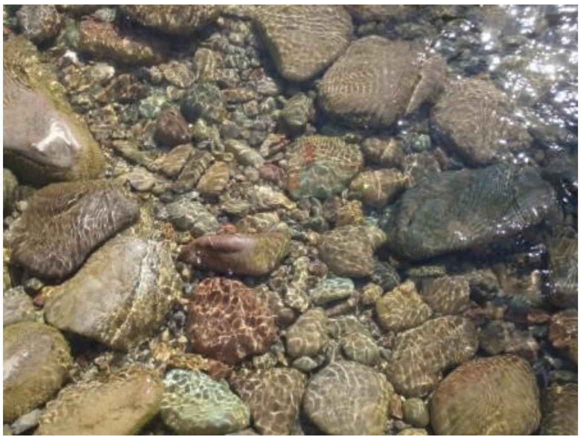
Given clue for locating a suitable site for active stream sediment: The sample site must be at least 100 m upstream of major roads and railway lines. It was pointed out that the bed load of the stream (large boulders and stones) indicates that this is a high energy stream (see Figure 18*b,c*), and fine-grained sediment can only be found in traps. Where can such traps be found?

Some people knew the answer, behind and below large boulders, in this particular case (Figure 18*d*). According to the specifications of the field manual, aliquots of fine-grained active stream sediment is collected and placed in the bucket over a stretch of about 250-500 metres. In this case, however, for the demonstration of the sampling technique aliquots were collected from a stretch of about 20 m (Figure 18*e,f*).

a)

b)

c)



d)

e)

d)

Figure 18. Active stream sediment sampling: a) Sample site number [N24 and E31 denote that the Jajrud stream is situated in the 24th GTN cell north of the equator, and the 31st GTN cell east of the 0° (Greenwich) meridian, respectively, and S1 is the number of the 1st stream sediment sample]; b) General upstream landscape; c) Bed load; d) Collection of fine-grained stream sediment from traps behind large borders, and placing the aliquots in the white bucket; e) washing the fine-grained sediment through a <2 and <0.150 mm stainless steel sieves in this case, although nylon screens should be used; and f) leaving the fine-grained sediment to settle, whilst collecting other sample types, and then returning to pack the fine-grained <0.150 mm stream sediment, after slowly decanting the supernatant stream water.

Floodplain sediment sampling

Given clue for locating floodplain sediment: As the stream is downcutting its own bed, the floodplain sediment is expected to be deposited in this particular stream, under extreme flood conditions, so they should be looking for deposits of fine-grained sediment (low energy environments) over the bank of the stream. For the older floodplain sediment, they should also be looking for older sections.

In this case, nobody was able to locate suitable sites for the collection of floodplain sediment. Therefore, the trap where floodplain sediment was deposited was shown (Figure 19). This particular profile shows 4 floodplain sediment layers, with the bottom two being more indurated. The bottom floodplain sediment (60-75 cm) is collected first and the top (0-19 cm) second. The bottom floodplain sediment, if collected from a deep enough layer should show pristine conditions, while the top the present day conditions. It was stressed that they should always sample single layers, and although a 25-cm thick section is the recommended thickness, if the top and bottom layers are thinner, as in this case, these sections should be sampled and the thickness recorded on the field observations sheet.

The older floodplain sediment layers in the distant sections were shown (Figures 19*e,f*), which undoubtedly should indicate pristine conditions.

Another suitable floodplain sediment site was also shown.

Agricultural soil sampling

It was stressed that agricultural soil is not a recommended global baseline mapping sampling medium. However, in Europe it was sampled, because of European Commission regulations.

Given clue for locating agricultural soil: A field where plants of any type are grown.

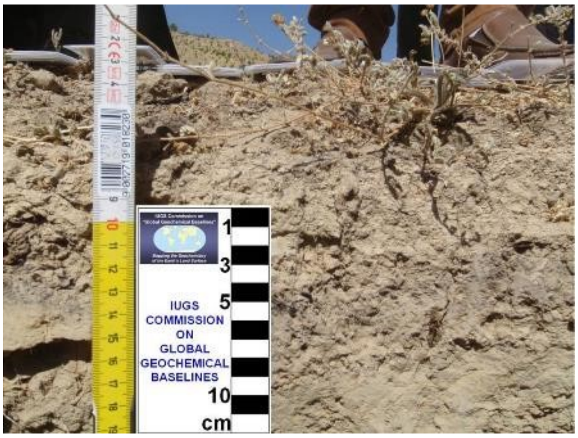
This was an easy sample medium to locate, because there was an agricultural field with kokab flower (Figure 20). A field composite sample down to a depth of 20 cm (ploughing depth) was collected from the corners and centre of a 10 x 10 m square. It was pointed out that this sampling scheme was stipulated in the European Commission regulation, and that we were obliged to follow it. It was stressed that the preferred sampling method that saves time and effort is the collection of the agricultural soil sample from a single pit.

a)

b)

c)

d)



e)

f)

Figure 19. Floodplain sediment sampling: a) Sample site number; b) General upstream landscape; c) Floodplain sediment profile; and d) Close-up of top floodplain sediment layer; e) and f) Layers of older floodplain sediment (light pale-yellow coloured horizons).

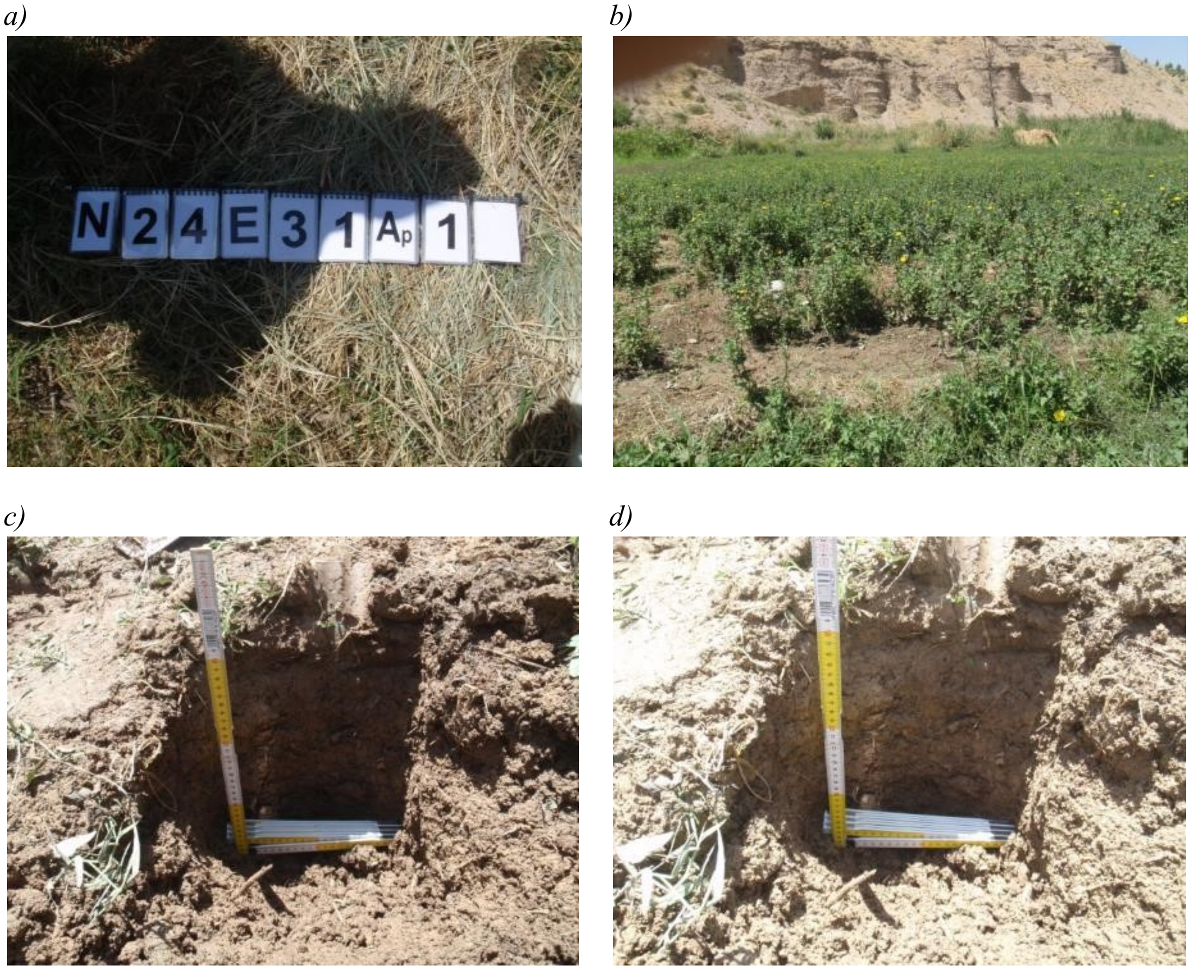


Figure 20. Agricultural soil sampling: a) Sample site number; b) General landscape; c) Ap soil profile without flash; and d) Ap soil profile with photographic flash.

Grazing land soil sampling

On the way back, a possible site for collecting grazing land soil sampling was shown (Figure 16). The area was covered by grass, and it did not appear to be cultivated. However, before sampling they should ask the landowner if the land was under grass cover for the last ten years.

Field observations and photographing

In all cases, the relevant field observation sheet was completed directly after sampling. It was stressed that, apart from noting the coordinates of the sample site from the GPS record, the sample site should be marked on the 1:50,000 topographical map, or digitally checked online using either Google Earth or a digital topographical map.

The digital photographic documentation is important, and the first photograph to be taken at each sampling site is the sample number, followed by the landscape and site.

7.2.5. Training Course on Geochemical Mapping and Environmental Geochemical Investigation for Developing Countries, 7-27 September 2017, UNESCO International Centre on Global-Scale Geochemistry, Langfang, China

The training course was sponsored by the Ministry of Commerce. In total, there were 38 participants from 17 countries, including Brazil, Cambodia, Eritrea, Madagascar, Mongolia, Montenegro, Morocco, Niger, Nigeria, Panama, Serbia, Seychelles, Sri Lanka, Surinam, Tanzania, Venezuela, and Zambia (Figure 21). The course was diverse, besides the lectures, a visit to Jinchuan Copper-Nickel Mining in Gansu Province was also organised, and included presentations, discussions and field visits that helped the participants to understand the geological survey conditions, mineral resource exploration, mining management in China, and other related issues. All the workshop participants attended the 2017 China Mining Congress, which was held at Meijiang International Convention Centre in Tianjin.

Figure 21. Group photograph of participants in the training course on Geochemical Mapping and Environmental Geochemical Investigation for Developing Countries, ICGG, Langfang, China.

7.2.6. 2017 Workshop on Geochemical Mapping for "Belt and Road" Countries, 23-30 September 2017, UNESCO International Centre on Global-Scale Geochemistry, Langfang, China

The Workshop was organised by the UNESCO International Centre on Global-Scale Geochemistry, and was attended by 15 participants from Cameroon, China, Mali, Mexico, Mongolia, Morocco, Russia, Uzbekistan, and Zambia (Figure 22). Four days were devoted to lectures, and one for demonstration in the field of the floodplain sediment collection procedure.

The principal tutors were Xueqiu Wang, Executive Director of the Centre (Figure 23*a*) and Alecos Demetriades, Chair of Sampling Committee (Figure 23*b*), with one lecture by Nie Lanshi and one by Gyozo Jordan (EuroGeoSurveys GEMAS project team) with another very short presentation.

The attendees were encouraged to present a 20-minute presentation of their work on the fifth day of the workshop.

Figure 22. Group photograph of 2017 Workshop on Geochemical Mapping for "Belt and Road" Countries participants.

a) b)

Figure 23. (a) Xueqiu Wang, and (b) Alecos Demetriades lecturing in the 2017 Workshop on Geochemical Mapping for "Belt and Road" Countries.

Sunday 24 September 2017

The Workshop participants attended the 2017 China Mining Congress and Expo, which was organised at the Tianjin Meijiang Conference and Exhibition Centre, Tianjin, China (https://10times.com/china-mining).

Monday 25 September 2017

- Introduction to the UNESCO International Centre on Global-Scale Geochemistry (ICGG) by Xueqiu Wang
- Introduction to Geochemical Mapping: Principles and Methodology by Xueqiu Wang

- Introduction to Applied Geochemistry (including Exploration Geochemistry) by Alecos Demetriades

Tuesday 26 September 2017

- Sampling at the European continental scale by Alecos Demetriades
- Sample preparation, sample randomisation, insertion of control samples and submission to laboratory, and FOREGS laboratory scheme by Alecos Demetriades
- Geochemical data management and map generation by Alecos Demetriades
- Quality control scheme (Independent Quality Control, and elaboration of different statistical techniques for data validation) by Alecos Demetriades
- Application of geochemical mapping for mineral exploration and environmental assessment by Alecos Demetriades
- Visit to Geochemical Laboratories and explanations by Yao Wensheng

Wednesday 27 September 2017

Demonstration of the Chinese floodplain sediment sampling technique by Xueqiu Wang (Executive Director of ICGG and Commission Co-chair), and the FOREGS internationally used floodplain sediment sampling technique by Alecos Demetriades (Chair of Sampling Committee) - refer to section on *"Comments on the Chinese floodplain sediment sampling technique"*). The selected site is on the right bank of the Chaobai River to the south of Baodi village, Tianjin (Figure 24), which is about 55 km to the ENE of Langfang (Coordinates: Longitude 117° 17' 6.06" E and Latitude 39° 40' 17.06" N in GTN grid cell N27E65).

Figure 24. Floodplain sediment sample site within GTN grid cell N27E65 on the right bank of the Chaobai River to the south of Baodi village, Tianjin, China.

Xueqiu Wang explained the floodplain sediment sampling procedure. The sample can be collected from exposed sections of the riverbank in the routine survey, but for monitoring purposes, a suitable site on the floodplain is selected. The reason is that the exposed bank sections are vulnerable to erosion and anthropogenic contamination, and are not suitable for monitoring. A composite sample is made from the apices of a 50-m equilateral triangle. He pointed out that in this particular section of the river, because of the elevated road, above the present highest flood level, older floodplain sediment can be found on the other side of the road. The field sampling procedure is shown in Figure 25, and explained in the caption.

a)

b)

c)

d)

e)

f)

Figure 25. Chinese floodplain sediment sampling technique: a) Clearing floodplain sediment sample site from surface vegetation; b) Digging pit down to 25 cm for the collection of the top floodplain sediment, and collection of top floodplain sediment sample; c) Use of soil auger for the collection of the bottom floodplain sediment sample from 100 to 150 cm; d) Retrieved aliquot of bottom floodplain sediment sample; e) Placing the floodplain sediment aliquot in cotton bag; and f) Sealed cotton bags containing the top and bottom floodplain sediment samples, and GPS unit showing the coordinates of the sample site.

Thursday 28 September 2017

- China Geochemical Baselines: Quantifying environmental changes by Xueqiu Wang

- Geological exploration data: Processing and analysis system by Nie Lanshi

Friday 29 September 2017

- Discussion on the Field Training Course, Chaobai River, Tianjin, on Wednesday 27 September 2017 by Alecos Demetriades
- Mexican Geological Survey: Research Centres by Flor De Maria Harp Hurribarria
- Status of geochemical mapping in Morocco by Mohamed Ghazali and Lahcen Ousaid
- Estudio geoquímico de los suelos en México by Jessica Rivera Pérez
- The methodology for creation of geochemical maps of the Russian Federation by Bobkov Roman and Mezhelovski Alexey
- Geological research and exploration stage of Mongolia by Munkhbileg Namsrai
- 2017 Geochemical mapping status in Zambia by Nyimbili Chibeza and Abel Kabele
- GEMAS: Spatial pattern analysis of Ni by means of digital image processing techniques on European agricultural soil data by Gyozo Jordan, Attila Petrik, Benedetto de Vivo, Stefano Albanese, Alecos Demetriades, Martiya Sadeghi and The GEMAS Project Team
- Google Earth maps by Gyozo Jordan
- International Cooperation: Global Geochemical Baselines Project; Mapping Chemical Earth Programme; Global, National, Monitoring; Data Management and Applications by Xueqiu Wang

Discussion: The MoU signed between China Geological Survey and Geological Survey of Mexico was discussed with Flor De Maria Harp Hurribarria and Jessica Rivera Pérez, who stated that there was disagreement with Xueqiu Wang (Executive Director of the UNESCO International Centre on Global-Scale Geochemistry) with respect to compositing the individual samples collected in each Global Terrestrial Network of 160 x 160 km to make an artificial laboratory sample. Again, as in the case of Iran, all samples will be analysed at the laboratory of the Geological Survey of Mexico.

Comments on the Chinese floodplain sediment sampling technique

The following comments were made with respect to the floodplain sediment sampling, and discussed in the Friday 29 September 2017 lecture entitled *"Discussion on the Field Training Course, Chaobai River, Tianjin, on Wednesday 27 September 2017"* by Alecos Demetriades:

1. The floodplain sediment was recorded and numbered as floodplain sediment on the field observations sheet, but subsequently the top and bottom samples were classified as soil samples collected from the A- (0-25 cm) and B-horizons (100-150 cm), respectively. This is very confusing, and it was pointed out that the correct terminology must be used, in this case overbank or floodplain sediment. Soil scientists may call the overbank or floodplain sediment as alluvial soil, but the applied geochemist should use the established terminology of overbank sediment (Ottesen et al., 1989), and the distinction made between overbank and floodplain sediment, according to the size of the drainage basin (Darnley et al., 1995).
2. Sampling at constant depths of 0-25 and 100-150 cm for the top and bottom samples, respectively, without any consideration of sampling different horizons, will most likely produce dubious results, as it has already been demonstrated with an example in the lecture *"Introduction to Applied Geochemistry (including Exploration Geochemistry)"* by Alecos Demetriades. Each overbank or floodplain sediment horizon, as it has been shown by the Regional Geochemistry Working Group of the Western European Geological Surveys

(subsequently FOREGS and presently EuroGeoSurveys), each sediment layer has its own distinct chemical composition, depending on the erosion points that are active at that particular flood event, and the geochemistry may vary considerably if the drainage basin has been affected by human activities (Bölviken et al., 1996). Therefore, the sampling must be horizon based, and two or more overbank or floodplain sediment horizons must not be mixed during sampling. Figure 26 shows the N27E65F1 floodplain sediment sample site dug up at the exposed section of the riverbank. The photographs (Figures 26*c,d*) clearly show that there are at least four floodplain sediment layers, i.e., 0-14 cm, 14-28 cm, 28-42 cm, and 42->60 cm; the section was not dug up deeper, because the water table is at a depth of about 70 cm. The top layer of 14 cm thickness is certainly not the A-horizon. It is quite apparent from this section that the deeper sample from 100-150 cm has been collected from different overbank or floodplain sediment horizons. Therefore, the solution for the Global Geochemical Baselines project, as each floodplain sediment sample is very significant, is to dig up a single pit down to a depth of 200 cm, because the three-dimensional information is important, and to collect the top and bottom overbank or floodplain sediment samples from single horizons. Although the specified thickness of each sample is 25 cm, if the top and bottom horizons are thinner, then the thinner horizon should be sampled in each case, and the deviation noted on the field observations sheet.

3. A painted shovel (Figure 25*b*) was used for digging up the pit down to a depth of 25 cm for the collection of the top overbank or floodplain sediment sample (certainly not soil). An unpainted or stainless steel shovel must be used, as it has already been pointed out in the lecture *"Sampling at the European Continental Scale"* by Alecos Demetriades.
4. The logic of collection of a composite field sample from the apices of a 50-metre equilateral triangle is not understood. It is considered a waste of time and effort to collect field composite samples, and is strongly recommended that this practice should cease, and overbank or floodplain sediment samples must be collected from single pits, as it has been done in (a) the FOREGS Geochemical Mapping of Europe (Salminen et al., 1998), and (b) the North American Soil project (Smith et al., 2013), and it is also the recommended sampling procedure in urban geochemical mapping (Demetriades and Birke, 2015a,b).

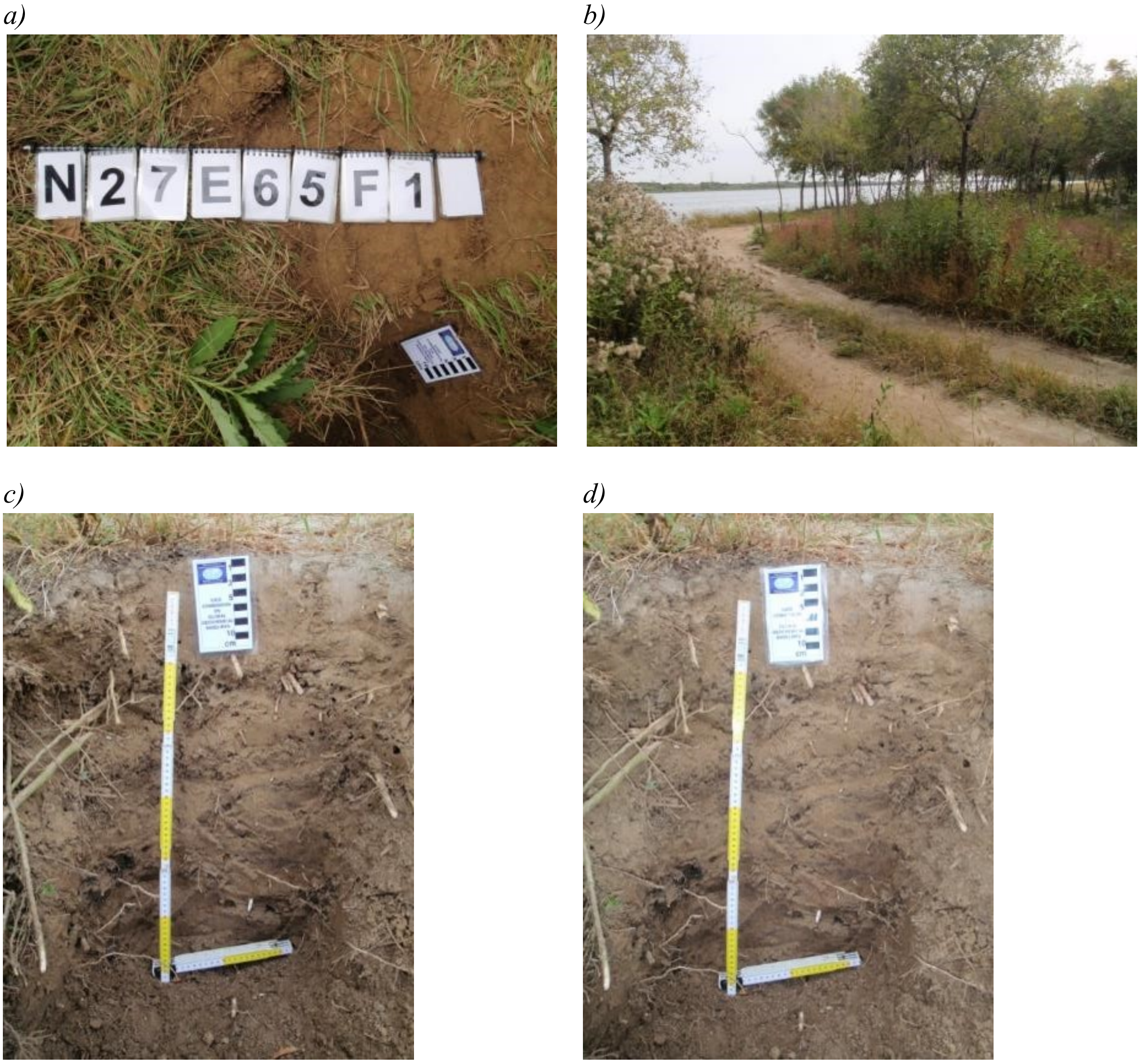


Figure 26. FOREGS internationally used floodplain sediment sampling technique: a) Floodplain sediment sample site number; b) Landscape photograph taken from the site where the composite floodplain sediment sample of Figure 25 was collected; c) Dug up floodplain sediment profile showing the different horizons (natural light); and d) Same floodplain sediment profile taken with fill-in flash. Note: At least four floodplain sediment horizons can be distinguished: 0-14 cm, 14-28 cm, 28-42 cm, and 42->60 cm.

7.2.7. 1st Ice-Breaking Workshop on Global Black Soil Critical Zone Geo-ecological Survey (BASGES), Shenyang Geological Survey, Shenyang, China, 8-12 December 2017

The workshop was held in Liaoning Mansion Hotel, 105 Huanghenan St., Huanggu District, Shenyang, China. The host was Professor Daming Wang, Assistant Director of Shenyang Geological Survey of China Geological Survey.

The Black soils, known as mollisols (from Latin *mollis*, "soft"), are the soils of grassland ecosystems (https://www.cals.uidaho.edu/soilorders/mollisols.htm). They are characterised by a thick dark surface horizon. This fertile surface horizon, known as a mollic epipedon, results from the long-term addition of organic materials derived from plant roots. Mollisols primarily occur in the middle latitudes (see Figure A1 in Appendix A). Globally, they occupy approximately 7.0% of the ice-free land area (approx. 9,200,000 km^2). Mollisols are among some of the most important and productive agricultural soils in the world and are extensively used for this purpose.

The Shenyang Geological Survey of China Geological Survey (SGS) has initiated an international collaborative project on Global Black Soils Critical Zone Geo-Ecological Survey (BASGES) to survey and compare the four black soil zones on the earth from the point of view of Earth Critical Zone.

The IUGS Commission on Global Geochemical Baselines was invited to participate in this initiative, and to contribute in the compilation of an IGCP project proposal. The invitation was discussed by the IUGS-CGGB Steering Committee, and it was decided to actively participate in this initiative, and offer its expertise in the:

1. Sampling design;
2. Laboratory treatment of samples;
3. Quality control scheme, and
4. Quality control check – verification of results.

The actual meeting was held on Saturday 9 and Sunday 10 December 2017, with a field trip on Monday 11 December 2017. The two-day programme included presentations, and a discussion in the afternoon of the second day. In total, there were 58 participants from China, Australia, Europe, and North America (Figure 27).

The FOREGS Geochemical mapping of Europe, and the pilot and research work of the Working Group on Regional Geochemical Mapping of the Western European Geological Surveys (WEGS) was presented by Alecos Demetriades. Manfred Birke presented the Geochemical mapping of Agricultural and Grazing land soil in Europe (GEMAS). Douglas Howard presented the continental-scale soil geochemical mapping of the Conterminous United States of America. Finally, Alecos Demetriades presented the input of the Commission during the discussion session. Details of the three-day programme are given below.

Figure 27. Group photograph of 1st BASGES Workshop, Shenyang, China.

Saturday 9 December 2017

- Welcoming speeches by Wang Daming (host), Li Zhizhong, Wang Xun, Peng Suping and others
- Introduction by Wang Daming (host)
- BASGES Initiative by Wang Daming
- Critical Zone and Soil Research by Chen Shuwang
- Critical Zone Observatory Research Review and Future by Timothy Filley
- Canadian Black Soil Research Review and Future by Geng Xiaoyuan
- Rock and Soil Ecological Geochemistry by Chen Shuwang
- Russian Black Soil Research Review and Future by Igor Savin
- Constructing an integrated modelling system for BSCZ by Wang Lei
- Soil Geochemical Survey by Dai Huimin
- WEGS and FOREGS Geochemical mapping of Europe by Alecos Demetriades
- GEMAS Research Review and Future by Manfred Birke
- Ukraine Black Soil Research Review and Future by Vladimir Klos
- Black Soil Geochemical Survey of China by Dai Huimin

Sunday 10 December 2017

- EuroGeoSurveys Soil Remote Sensing Research Review and Future by Veronika Kopackova
- USGS Soil Remote Sensing Research Review and Future by Douglas Howard
- Global Soil Spectral Lib Research Review and Future by Raphael Viscarra-Rossel
- Air-borne Hyperspectral Remote Sensing Black Soil Applications by Zhao Yingjun
- Satellite Remote Sensing Black Soil Applications by Chen Jiang
- Black Soil Spectral Library Construction and Applications by Chen Shengbo
- Discussion about the BASGES Future by Wang Daming
- Input to BASGES project by the IUGS-CGGB by Alecos Demetriades, David B. Smith and Patrice de Caritat (This contribution is in Appendix A of this report).

It is noted that the IUGS-CGGB was the only body that prepared a presentation about its input to BASGES project, and also the points that there was disagreement in the IGCP proposal *"Land resource evolution mechanism and its sustainable use in global black soil critical zone"*, which was submitted a day before the deadline of 15 October 2017.

Monday 11 December 2017

Before boarding the minibus it was announced that temperature in the Gongzhuling area, where the black soil profile was dug up in November, was expected to be -17°C. Only two of the foreign people finally decided to join the field trip, Manfred Birke (Commission Contact person from Germany) and Alecos Demetriades (Chair of Sampling Committee). The Shenyang Geological Survey geoscientists, included Dai Huimin, who is in charge of the Black Soil Geochemical Survey, Liu Kai, the field applied geochemist and Bao Qingzhong, geologist. After a three-hour trip the site of the black soil profile was reached. The photographs in Figure 28 show the extreme weather conditions. Liu Kai explained the black soil profile (Figures

28*c,d*), and after twenty minutes in the cold field conditions the minibus was boarded, and returned back to Shenyang.

Tuesday 12 December 2017

Alecos Demetriades (Sampling Committee Chair) had a two-hour meeting with Dai Huimin and Liu Kai. The Commission proposal was discussed in detail, and all questions answered.

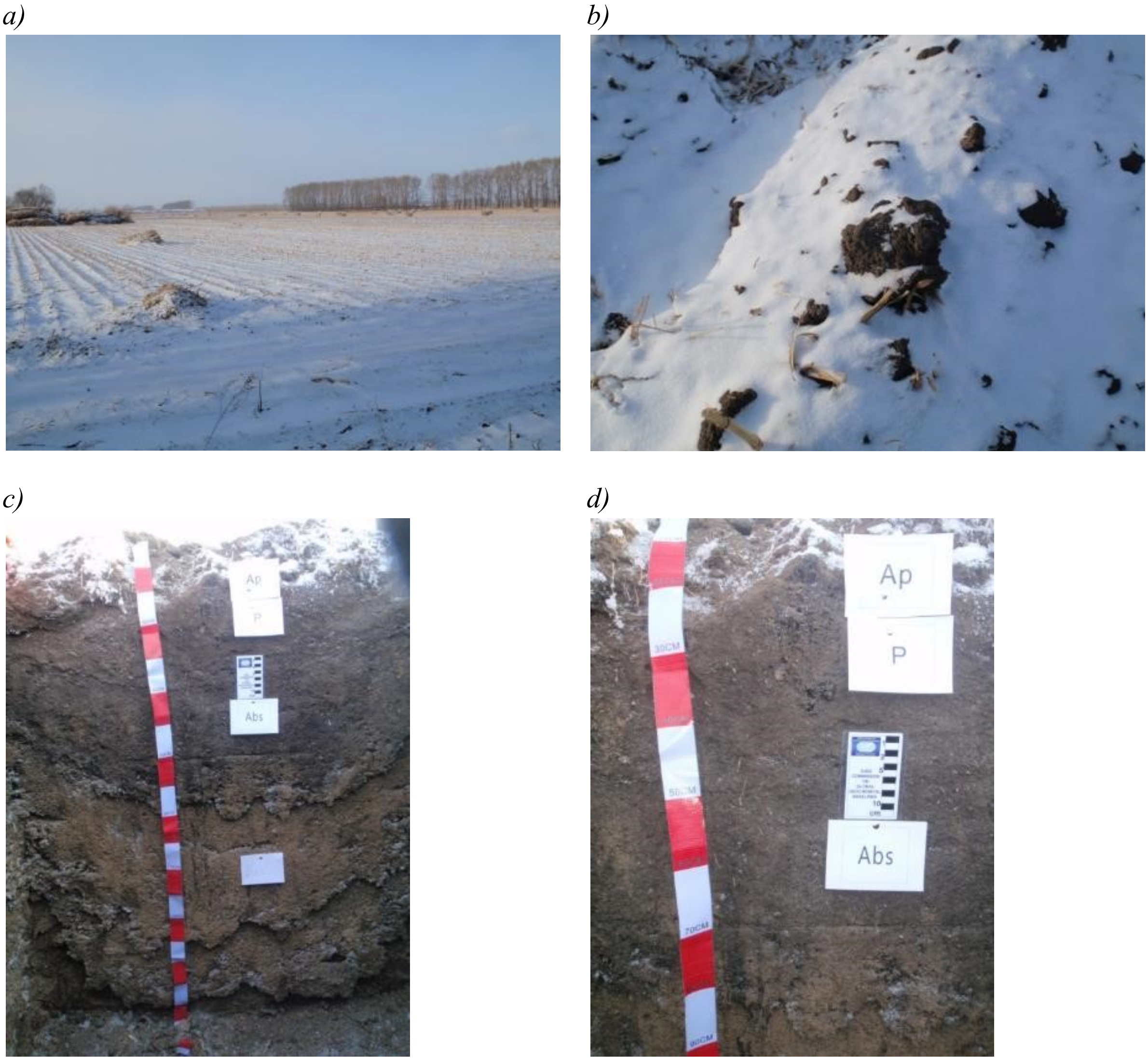


Figure 28. Gongzhuling area, 220 km to the NE of Shenyang: a) Mollisols landscape; b) Black soil protruding from the ice-covered landscape; c) Mollisols soil profile; and d) Close-up of top black soil profile.

International Black Soil Society

Wang Daming informed all Workshop participants about the establishment of the International Black Soil Society (IBSS), which is a non-profit and voluntary society that will provide an open international collaboration platform, aiming to integrate and provide research resources including background research, professional teams, and funds applications about black soil research. Wang Daming invited all scientists, participating in the 1st BASGES workshop, to be members of the scientific board and their institutes as collaboration institutes. He stressed that IBSS will be very open to world top scientists and institutes to join. Further, a website has already been registered: http://www.blacksoils.org/, and will be operational in the next few months.

Global Geochemical Mapping MoU signed between IUGS and CGS

An MoU on Global Geochemical Mapping of five year duration was signed by the IUGS and the CGS in Tianjin (China) on 22 October 2014. The IUGS has always given vigorous support to global geochemical mapping through the IGCP 259 (1989-1993) and IGCP 360 (1994-1997) programmes, and the IUGS Task Group then Commission on Global Geochemical Baselines (1997 to present). According to Article 5 of the MoU, "IUGS will communicate with its adhering Organisations and encourage them to provide necessary assistance for global sampling and experiments related to research and training projects jointly supported by CGS and IUGS under the framework of the International Centre on Global-Scale Geochemistry and the IUGS/IAGC Task Group on Global Geochemical Baselines". The co-operation between CGS and IUGS in global geochemical mapping may be effected by:

- Launching Global Geochemical Baselines Mapping Project - Chemical Earth, and to promote the establishment of a global network for the project and to develop partnerships with countries and organisations.
- Fostering and supporting the implementation of global-scale geochemical mapping in developing countries;
- Providing consultation and training in the form of workshops and short courses for scientists, engineers and postgraduate students on the basis of up-to-date global-scale geochemical knowledge and methodology, and providing technical assistance to developing countries;
- Organising periodic international symposia to foster communication among the geochemical mapping community, for instance at International Geological Congresses; and
- Promoting equal access to basic services and knowledge sharing, and developing a bridge between the scientific community, decision-makers and the general public in the field of geochemistry.

International Centre on Global-Scale Geochemistry approved by UNESCO

The Proposal for the establishment of the International Centre on Global-Scale Geochemistry in Langfang, China, under the auspices of UNESCO as a Category 2 Centre, was approved by the 37th session of UNESCO in Paris on 13 November 2013, and approved by China Government in September 2015.

Since the 1980s, in light of the importance of global geochemical baselines for recognition of global environmental changes, formidable efforts have been made by applied geochemists through the International Geochemical Mapping Project (IGCP 259), the Global Geochemical Baselines Project (IGCP 360), and the IUGS/IAGC Task Group (now Commission) on Global Geochemical Baselines. However, progress has been slow and limited, as foreseen by Darnley et al. (1995) in the final report of IGCP Project 259: "*Because of the number of organizational and technical steps involved it seems highly unlikely that any group of scientists convened under a non-government organization, however enthusiastic, could sustain or manage an international sampling activity (other than as a small test project in a sympathetic jurisdiction) over the period of time required for completion... Assuming the importance of the geochemical information to be obtained is recognized by the international scientific community, there is a clear need for a single permanent agency to accept formal responsibility for securing funds, managing and coordinating these activities according to scientific guidelines determined by an external advisory committee*."

In the past twenty years, experience and lessons have made it clear that there is an urgent need for the establishment of a single permanent agency to accept formal responsibility for securing funds, managing and coordinating these activities according to scientific guidelines determined by an external advisory committee.

In September 2009, Prof. Xie Xuejing (China), Dr. David Smith (USA) and Dr. Wang Xueqiu (China), forwarded a proposal to the China IGCP National Committee for establishing an International Research Centre on Global Geochemical Mapping (The name was subsequently changed to International Centre on Global-Scale Geochemistry) under the auspices of UNESCO. The proposal had also been thoroughly discussed by the participants of the Global Geochemical Mapping Symposium held in Langfang China (9-12 October 2009). All participants expressed their support for establishment of an International Research Centre for Global Geochemical Mapping at the IGGE in Langfang, China.

The proposal was supported by the Ministry of Land and Resources of China, the International Union of Geological Sciences (IUGS), the Association of Applied Geochemists (AAG), the Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP), the IUGS/IAGC Task Group (now Commission) on Global Geochemical Baselines, the China Geological Survey (CGS), the Chinese Academy of Geological Sciences (CAGS), and the Geological Society of China.

In October 2010, the Ministry of Land and Resources formally requested the Director-General, through the Permanent Delegation of the People's Republic of China, that UNESCO carry out a feasibility study for the establishment of a Category 2 Centre in Langfang, co-located with the IGGE (State Research Institute). The IGCP Scientific Board reviewed the feasibility study report and made a resolution in support of the proposal at the 39th IGCP Scientific Board Meeting, 16-18 February 2011. The decision was adopted by the UNESCO Executive Board at its 191st session in Paris on the 3 June 2013. Finally, the proposal was approved by the General Conference at its 37th session in Paris on 13 November 2013. The Centre has been approved by the State Council-China Government (September 2015), and the final procedure authorisation for the signing of the agreement by the China Geological Survey with UNESCO was approved by the Ministry of Foreign Affairs of China.

The Centre will foster knowledge and technology for documenting global-scale geochemical data and accompanying distribution maps, sustaining development for natural resources and the environment, and act as the platform for training and transferring up-to-date knowledge and technology between the developed and developing countries, and promote equal access to basic services in the field of global-scale geochemistry.

On 12 May 2016, during the official opening ceremony in the newly constructed building within the premises of Institute of Geophysics and Geochemistry (IGGE) in Langfang, China, the Agreement between UNESCO and China for the establishment of the International Centre on Global-Scale Geochemistry was signed (Figure 29).

Figure 29. Building of the UNESCO International Centre on Global-Scale Geochemistry, Langfang, China.

A Global Geochemical Mapping Programme via the Centre was approved by China Government through the China Geological Survey. A six-year term financial support plan (2016-2021) for Global Geochemical Mapping was submitted by the China Geological Survey via the Ministry of Land and Resources, and a budget of approximately Yuan 200M (approximately US$ 29M or € 27M) per year was approved by the Ministry of Finance.

Professor Wang Xueqiu (wangxueqiu@igge.cn, geochemistry@sina.com), as the Executive Director of the Centre and 2nd Chairperson of the Commission, is the project leader for the coordination of the programme. Any countries that are interested to participate in the programme may contact him directly.

7.3. CHIEF ACCOMPLISHMENTS IN 2017

1. Redesigning of the Commission's website, which is expected to be uploaded in the first quarter of 2018.
2. Reporting at the 71st IUGS Executive Committee Meeting, 15-18 February 2017, Paris.
3. Joint business meeting of the EuroGeoSurveys Geochemistry Expert Group and IUGS Commission on Global Geochemical Baselines (20-21 April), Geological Survey of Austria, Vienna
4. Short Training Course on the use of Geochemical Software for Geochemical Map Generation, Laos, 23-25 April 2017.

5. Organisation of a two-day workshop on *'Global Geochemical Mapping'* (29-30 August 2017) on the occasion of the 4th YES Congress on *'Mitigating Geohazards and Resources for Future Generations'*, Geological Survey of Iran, Tehran, Iran.
6. Training Course on Geochemical Mapping and Environmental Geochemical Investigation for Developing Countries, UNESCO ICGG, Langfang, China, 7-27 September 2017.
7. Collaboration with the UNESCO International Centre on Global-Scale Geochemistry (ICGG) in the organisation of the 2017 Workshop on Geochemical Mapping for *'Belt and Road'* Countries, 23-30 September 2017, Langfang, China.
8. Collaboration with the UNESCO ICGG Secretary Office in the finalisation and publication of the Centre's first Newsletter, which is available for downloading at http://www.globalgeochemistry.com/en/main.php?action=displaybody&s=107&pid=157.
9. Participation in the 1st Ice-Breaking Workshop on *'Global Black Soil Critical Zone Geo-ecological Survey (BASGES)'*, Shenyang Geological Survey, Shenyang, China, 8-12 December 2017.
10. Acting on the request of the YES Network to the RFG2018 Organising Committee for the organisation of a Workshop, the IUGS-CGGB has collaborated with the Association of Applied Geochemists (AAG). Peter A. Winterburn, the convenor of the AAG Workshop on *"Exploration Geochemistry: From fundamentals to the Field"* agreed to include two additional lectures by the Commission, and made special arrangements for the participation of YES Network members. The lectures will be held on Sunday 17 June 2018. John L. Gravel, who is responsible for the field-training course, collaborated very closely with the Chair of the Sampling Committee, and organised a one-day field-training course on Friday 22 June 2018. Arrangements have been made to visit the field area on Tuesday 19 June 2018, in order to prepare the sampling sites.

The Commission supported partly or wholly the travelling and sustenance expenses of the Sampling Committee Chair to participate at some of the above mentioned events, i.e., (3) and (5), and (9), and the Treasurer for (2).

7.4. Work Plan for 2018

7.4.1. Business Meetings of the Commission

The next business meeting of the Commission will take place in Madrid (May 2108) in conjunction with the annual meeting of the EGS Geochemistry Expert Group. A short business meeting will be organised on the occasion of RFG2018 in Vancouver (June 2018).

7.4.2. Field Sampling Manuals

The mandate of IUGS Commissions is to set standards. Hence, the IUGS Commission should set the standards for Global-scale Geochemical Baseline Mapping according to 'Blue Book' (Darnley et al., 1995) specifications in all the major terrestrial morpho-climatic terranes found on Earth.

For historical reasons it was decided to leave the FOREGS Geochemical Mapping Field Manual (Salminen et al., 1998) as it is, because it deals with sampling in Temperate and Mediterranean terranes.

An additional field manual, according to 'Blue Book' (Darnley et al., 1995) specifications, is under preparation by the Commission, and although this was planned to be published in 2017, it was not possible due to financial constraints. This field manual will include sampling instructions, mainly for soil, in (a) Karstic terranes, prepared by Alecos Demetriades, Simon

Pirc, Milan Bidovec and France Šušteršič (completed), (b) Desert terranes by Xueqiu Wang, (c) Tundra terranes by Xueqiu Wang, (d) Arctic terranes by Rolf Tore Ottesen, and (e) Tropical terranes by Alecos Demetriades, Xueqiu Wang, Christopher C. Johnson, Reijo Salminen and others. Further, the 'Blue Book' needs to be revised, because there are contradictions in the methodology.

As the field sampling manuals are very important, not only for the Global Geochemical Baselines project, but also for any applied geochemical survey, they are planned to be accompanied by video films, which will be uploaded to YouTube and Facebook.

7.4.3. Capacity Building Workshops

In 2012, the Task Group received inquiries from Iran and Brazil about conducting training in geochemical mapping. Because of financial problems in most surveys no further action was taken during 2013-2017. New opportunities developed in 2014 with the invitation from the Geological Survey of Iran (GSI) for a one-day workshop on *"Global Geochemical Baselines"*, and a keynote presentation at the plenary session of the 1st International Conference in Iran. Field training was undertaken by the IGGE, after an MoU was signed between GSI and China Geological Survey.

Similarly, following the two-day workshop in Dar-es-Salaam (Tanzania) in 2014, the Geological Society of Africa (GSAf) would like to pursue training opportunities in African countries in Global Geochemical Baselines methods. Although the contents of the MoU have been agreed, it was not signed, because GSAf has not yet found sponsorship. Therefore, it may be possible, if GSAf finds the necessary funds from sponsors, to organise the first training workshop in 2018.

At the invitation of the Young Earth Scientists Network (YES), a two-day capacity building workshop is planned on the occasion of the RFG2018 in Vancouver (17 and 22 June 2018). The Workshop is organised in collaboration with the Association of Applied Geochemists.

Other capacity building workshops will be organised in collaboration with the UNESCO International Centre on Global-Scale Geochemistry.

7.4.4. Communication and Dissemination Plans

The Commission, and all national- and continental-scale geochemical mapping projects being carried out in many countries, plan to continue active participation in national and international symposia, conferences and workshops for the promotion of global-scale geochemistry.

Communication will also be achieved through continued output of peer-reviewed scientific papers.

In addition, the Commission's website will be a key forum for communication and dissemination of information, and the plan is to include links to popular social media, such as Facebook, Twitter, YouTube, Linkedin, Pinterest, Google Plus+, etc.

7.4.5. Conferences

16-21 June 2018: RFG2018 – Resources for Future Generations, Vancouver Convention Centre, Vancouver, BC, Canada (http://www.rfg2018.org).

The Commission is a Technical Partner in RFG2018 (http://www.rfg2018.org/sitecore/content/RFG/2018/Rfg-Highlights/Partner-Organizations), and is organising (a) a session on *"Global-Scale Geochemical Mapping: A Critical Component for Resourcing Future Generations"* (RS24) under the theme *"Resources & Society"*, and (b) a two-day Workshop in collaboration with the Association of Applied Geochemists with the title *"Exploration Geochemistry: From fundamentals to the Field"*, 17 and 22 June 2018 (http://www.rfg2018.org/en/RFG/2018/Technical-Program/Workshops).

24-30 June 2018: A Code for Geological Fieldwork in Africa: Guidelines on Health and safety Issues in Mapping, Mineral Exploration and Geoecological Research, Sheraton Hotel and Towers, Abuja, Nigeria (http://physicalscs.unn.edu.ng/wp-content/uploads/sites/14/2017/11/CODE-CONCEPT.pdf).

The motivation for this initiative is underpinned by the urgent need to reinforce health and safety management (HSM) issues in geological fieldwork in Africa. The theme of the conference: *"A Code for geological fieldwork in Africa"* could never have been more apposite at this time, as we continue to record more and more unsavoury incidents during geoscientific fieldwork.

The Conference would bring to light the virtual absence of regulatory guidelines in conducting geological fieldwork by many geoscience departments, mineral exploration companies and mining establishments in Africa, and highlight the importance of mitigating health and safety challenges identified from the ethical, legal, economic and other dimensions.

Chair of Organising Committee is Prof. Theophilus Clavell Davies (Department of Geology, University of Nigeria Nsukka, 410001 Nsukka, Nigeria), who is the Commission's Regional Representative for Africa.

8. SUMMARY OF EXPENDITURES IN 2017

8.1. USAGE OF IUGS ALLOCATION

The usage of the allocated 2017 funds of US$ 4500 is tabulated below.

Event/Category	Cost description	Cost in US$
Bank Charges on the IUGS grant		3.26
71st IUGS EC meeting, UNESCO Fontenoy Building Paris (15-18 February 2017). Participation and reporting by Commission Treasurer of the 2016 work, and 2017 schedule	Travel expenses, incl. insurance	252.31
	Hotel	677.60
	Food expenses	88.00
	Bank transfer charges	7.73
Joint Meeting of EuroGeoSurveys Geochemistry Expert Group and IUGS Commission on Global Geochemical Baselines, Geological Survey of Austria (20-21 April 2017). Participation and reporting of Sampling Committee Chair	Travel expenses, incl. insurance	450.94
	Hotel	432.56
	Food expenses	120.11
	Bank transfer charges	7.78
Purchase of equipment for demonstration of sampling techniques in field training Workshops	Field equipment (e.g., stainless steel spade and scoop, plastic scoops, sample numbering system, boots, buckets, permanent ink markers)	311.28
	TubEx - Rilsan bags certified trace-element free bags	348.70
4th YES Congress, Geological Survey of Iran, Tehran, Iran (27-30 August 2017). Participation of Sampling Committee Chair: Keynote presentation in Opening Ceremony, and lecturing in two-day workshop, including demonstration of sampling techniques in the Commission sponsored field trip	Travel expenses, incl. insurance, Visa charges, metro fares, taxi, etc.	967.12
	Coach hire and packed lunches	600.00
1st BASGES Workshop, Geological Survey of Shenyang, Shenyang, China (8-12 December 2017); participation of Sampling Committee Chair	Local travel expenses, incl. insurance, Visa charges, and food in airports	142.65
Website design		1014.00
Website hosting fee (2017-2018)		281.23
Bank transfer charges		12.16
	Total 2017 expenses (US$):	**5717.43**

As is shown above the allocated 2017 amount of US$ 4500 was exceeded by US$ 1274.30, and this amount was covered by the existing reserve funds.

9. BUDGET FOR 2018 AND FUNDING SOURCES OUTSIDE IUGS

9.1. Funding of Global-Scale Geochemical Projects

The success of the IUGS Commission has to-date been almost entirely dependent on funding from sources outside the IUGS. This funding has come primarily from national Geological Surveys and other scientific institutions in participating countries. We conservatively estimate that over the past ten years, US$ 33M has been spent on broad-scale geochemical surveys, conducted according to recommendations from the IUGS Commission and its predecessors.

9.2. Funding from IUGS

Funding from IUGS has consisted of US$ 1500 per year for 2003-2008, US$ 4000 for 2009 and 2010, and US$ 5000 for 2011 and 2012, no funding for 2013, and US$ 5000 for 2014, 2015 and 2016, and for 2017 US$ 4500. The Commission currently has reserves of US$ 10,289.

9.3. Funding Request from IUGS for 2018

Taking into account:

- the necessity to publish in 2018 the Field Manual, and accompanying video films, for all the remaining terrane types,
- the need for field training courses and workshops in African and other countries,
- the need for the new Public Relations and Finance Chair to be informed, and
- the organisation of a dedicated session on *"Global-Scale Geochemical Mapping: A Critical Component for Resourcing Future Generations"*, and a two-day Workshop on *"Exploration Geochemistry: From fundamentals to the Field"* (the one-day field excursion is sponsored by the Commission) on the occasion of RFG2018 in Vancouver, Canada,

it is anticipated that the expenses for 2018 could reach US$ 20,000, as indicated in the table below. The Commission is, therefore, requesting financial support in the order of **US$ 15,000** from IUGS for 2018, because the current reserves, and the normal 5,000 US$ annual grant are not enough to cover the planned underlying expenses.

Event/Category	Cost in US$
72nd EC meeting, Potsdam, Germany (22-25 January 2018); Participation of Treasurer for reporting Commission's 2017 activities, and 2018 work plan (Travel expenses, insurance, hotel, and food)	1100
Joint Meeting of EGS Geochemistry Expert Group and IUGS-CGGB, Geological Survey of Spain, Madrid (15-19 May 2018); 2 persons participating (Chairs of Sampling Committee and Public Relations and Finance). The estimate includes airfares, insurance, hotel, food and local transportation	3500
RFG2018, Vancouver, Canada (16-21 June 2018); 2 persons participating; lecturing in Workshop "*Exploration Geochemistry: From fundamentals to the Field*", and organisation and presentations in a session under the theme Resources and Society (*RS24: Global-Scale Geochemical Mapping: A Critical Component for Resourcing Future Generations*). The cost includes airfares, insurance, hotel, food, local transportation, conference registration fee, etc.	8150
Sponsoring the one-day field training workshop, includes the coach hire and packed lunches for 50 people	2000
Workshop in Africa	5000
Website hosting fee 2018-2019	300
Total estimated cost in US$:	**20,050**

10. LINK TO IUGS WEBSITE

The Commission's website has a link to the IUGS website: www.globalgeochemicalbaselines.eu/?page_id=47.

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APPENDIX A

Input to BASGES project by the IUGS Commission on Global Geochemical Baselines

by Alecos Demetriades, David B. Smith and Patrice de Caritat

(http://www.globalgeochemicalbaselines.eu/)

December 2017

A1. STRUCTURE OF POWERPOINT PRESENTATION

- Introduction: Distribution and characteristics of mollisols
- Sampling scheme: Shenyang Geological Survey
- Additional comments on IGCP project proposal
- Sampling scheme
- Sample preparation
- Randomisation of samples and insertion of quality control samples
- Laboratory analysis
- Quality control check
- Summary of points and recommendations
- References and bibliography

A2. INPUT OF IUGS COMMISSION ON GLOBAL GEOCHEMICAL BASELINES TO BASGES PROJECT

The input will be in the:

1. Sampling design
2. Laboratory treatment of samples
3. Quality control scheme
4. Quality control check – verification of results

A3. INTRODUCTION: DISTRIBUTION AND CHARACTERISTICS OF MOLLISOLS

To begin with, a literature review was carried out and the two main sources of information on mollisols were found to be Liu et al. (2012) and the University of Idaho website (https://www.cals.uidaho.edu/soilorders/).

Mollisols (from Latin *mollis*, "soft") are the soils of grassland ecosystems. They are characterised by a thick, dark surface horizon. This fertile surface horizon, known as a mollic epipedon, results from the long-term addition of organic materials derived from plant roots. Mollisols primarily occur in the middle latitudes. Globally, they occupy approximately 7% (approx. 9,200,000 km^2) of the ice-free land area (Figure A1). Mollisols are among some of the most important and productive agricultural soils in the world and are extensively used for this purpose. Mollisols were sampled in Ukraine (Figure A2) during the EuroGeoSurveys Geochemistry Expert Group's project of geochemical mapping of agricultural and grazing land soil (GEMAS).

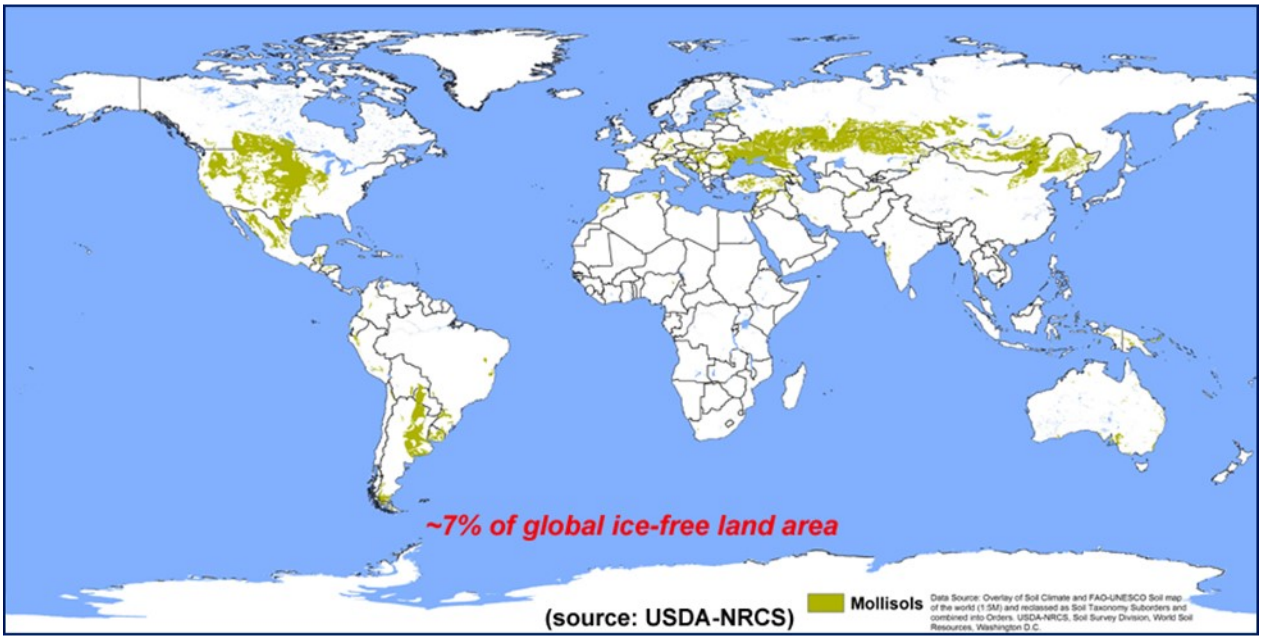


Figure A1. Global distribution of mollisols (Source: https://www.cals.uidaho.edu/soilorders/i/Mollisols.jpg).

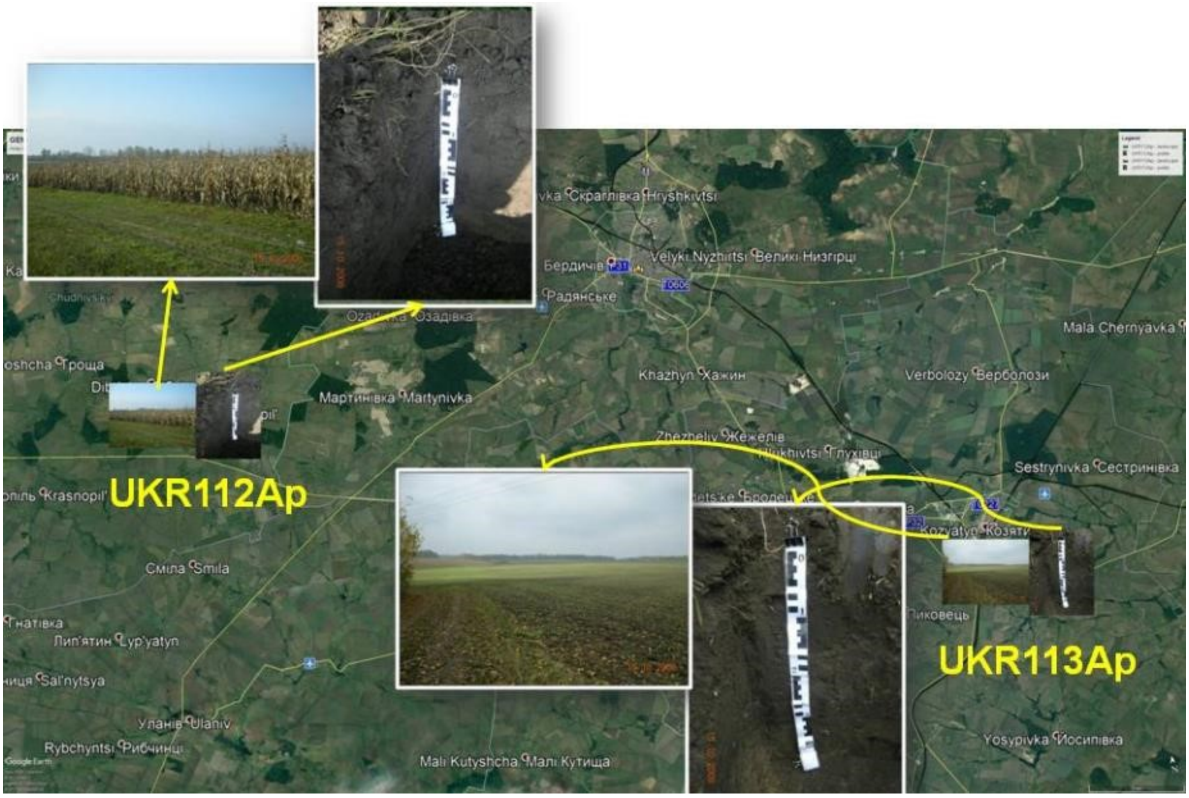
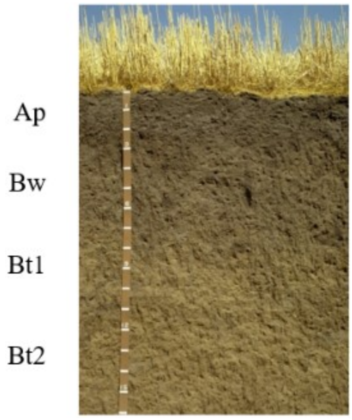


Figure A2. Mollisols in Ukraine from the EuroGeoSurveys' GEMAS project photograph archive (http://gemas.geolba.ac.at/Photos.htm). The landscape and profile photographs of two sample sites, UKR112Ap and UKR113Ap are shown on the Google Earth background.

Mollisols are divided into 8 suborders: Albolls, Aquolls, Rendolls, Gelolls, Cryolls, Xerolls, Ustolls, and Udolls (see Figures A3-A6) (https://www.cals.uidaho.edu/soilorders/mollisols.htm).

Haploxeroll landscape, Latah Co., Idaho
https://www.cals.uidaho.edu/soilorders/i/Moll_13b.jpg

This sloping landscape is characteristic of the Palouse region of eastern Washington and northern Idaho. Soils in these landscapes are formed in extremely thick deposits (>100 ft) of wind-blown loess. These soils have a high water holding capacity and high native fertility, making them very productive soils for dry land wheat production. However, soils are also highly susceptible to both wind and water erosion. Conservation tillage and high residue management systems have increasingly come into use in the Palouse region, in an attempt to slow the loss of valuable topsoil from agricultural fields.



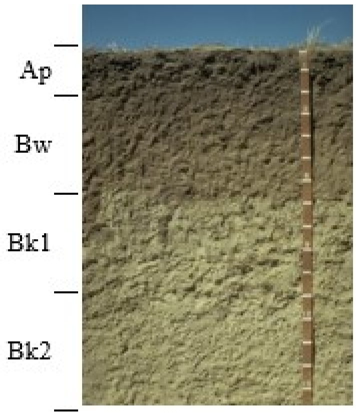
Fine-silty, mixed, superactive, mesic Pachic Ultic Haploxeroll (scale in decimetres)
https://www.cals.uidaho.edu/soilorders/mollisols_14.htm

This soil is typical of the deep loessial soil found in eastern Washington and northern Idaho. Soil formation took place under native grassland vegetation of primarily Idaho fescue and blue bunch wheatgrass; however, very little native vegetation remains on areas of Palouse soil, due to the soil's high agricultural productivity. The Bt horizons do not qualify as an argillic horizon in this soil because the increase in clay is too gradual. The mollic epipedon is quite thick, extending from the surface to an average depth of ~60 cm. Crops grown on Palouse soils include winter wheat, barley, dry peas, and lentils. Erosion is a major concern for the use and management of these soils.

Figure A3. Haploxeroll landscape, Latah Co., Idaho, United States of America.

Haploxeroll landscape, Telton Co., Idaho
https://www.cals.uidaho.edu/soilorders/i/Moll_11b.jpg

Soil developed in these loessial landscapes is very important and productive agricultural soil in the state of Idaho. This soil type has a high water holding capacity and can store water for long periods of time to be used by crops later. The water holding capacity makes for successful dry land cropping in the region. Irrigation is used where a water source is available. Potatoes, shown here, are the major irrigated crop grown in south-eastern Idaho.



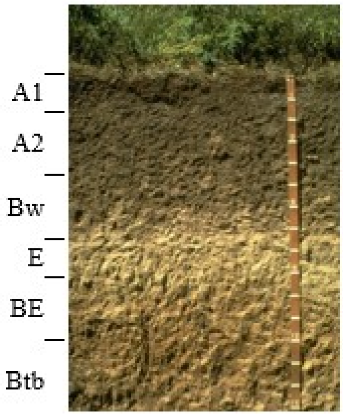
Coarse-silty, mixed, superactive, frigid Calcic Haploxeroll (scale in decimetres)
https://www.cals.uidaho.edu/soilorders/mollisols_12.htm

This soil type is formed on a thick deposit of calcareous loess. Calcium carbonate has been leached deeper in the profile, creating calcic horizons. The relatively cold, dry climate has slowed soil development and very little neoformation or subsoil accumulation of clay has taken place. This soil is related to the Palouse series of Washington and Idaho; however, because of a warmer and wetter climate, the Palouse series contains nearly twice as much clay.

Figure A4. Haploxeroll, Telton Co., Idaho, United States of America.

Argixeroll landscape, Benewah Co., Idaho
https://www.cals.uidaho.edu/soilorders/i/Moll_15.htm

Soil on these gently rolling landscapes is formed on thick deposits of loess. Much of this once-forested land has been cleared for agriculture. While this soil type can be very productive, erosion and drainage issues associated with the loess parent material and underlying argillic horizon, can present problems for its management.



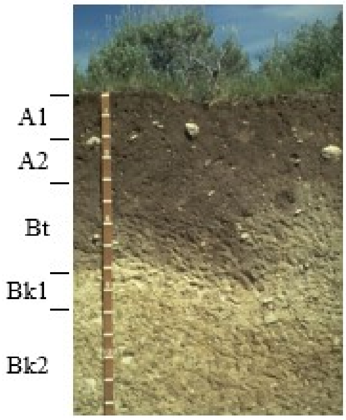
Coarse-silty, mixed, superactive, frigid Calcic Haploxeroll (scale in decimetres)
https://www.cals.uidaho.edu/soilorders/mollisols_12.htm

This soil belongs to the Southwick series and has developed on loess under ponderosa pine forest. The relatively open canopy and dense understory associated with ponderosa pine forest in this area is responsible for development of a mollic epipedon. The A-Bw horizon sequence has formed mostly on Holocene loess, while the Btb horizon represents the upper part of a late-Wisconsinan palaeosol. The Btb horizon is hydraulically restrictive with a saturated hydraulic conductivity of ~0.1 cm/day. Water is perched above this horizon for a period extending from late November through May.

Figure A5. Argixeroll landscape, Benewah Co., Idaho, United States of America.

Cryoll landscape, Lemhi Co., Idaho
https://www.cals.uidaho.edu/soilorders/mollisols_07.htm

Argicryoll is in the foreground, under a sagebrush and Idaho fescue habitat. This soil type is formed in $CaCO_3$-rich glacial outwash derived from the limestone mountains nearby. The cool climate and short growing season restrict the use of this soil type to primarily rangeland.



Fine-loamy, mixed, superactive Pachic Argicryoll (scale in decimetres)
https://www.cals.uidaho.edu/soilorders/mollisols_08.htm

Calcium carbonate in the subsoil is derived from the lime-rich parent material. These minerals dissolve in the upper profile where the moisture content is greater and there is abundant carbon dioxide. Calcium and bicarbonate leach downward and precipitate in the lower profile where there is less soil moisture and CO_2 levels are low. Clay translocation in the upper profile often begins following the downward movement of carbonates in the soil. In this soil, clay translocation is evidenced by the formation of the Bt horizon. Wavy horizon boundaries can be seen on the right side of the profile. These are the result of extensive animal burrowing, possibly badger in this case.

Figure A6. Cryoll landscape, Lemhi Co., Idaho, United States of America.

In north-east China, there is a large area covered with mollisols (black soil – see Figures A7, A8).

Figure A7. Shuangya Mountain Black soil wetland (Source: CAAC INFLIGHT MAGAZINE, 2017, Issue 12, No. 285, p.92-93).

Figure A8. Shuangya Mountain Black soil wetland (Source: CAAC INFLIGHT MAGAZINE, 2017, Issue 12, No. 285, p.96-97).

For the development of a high quality geochemical database, two stages are very important: sampling and sample preparation (Figure A9).

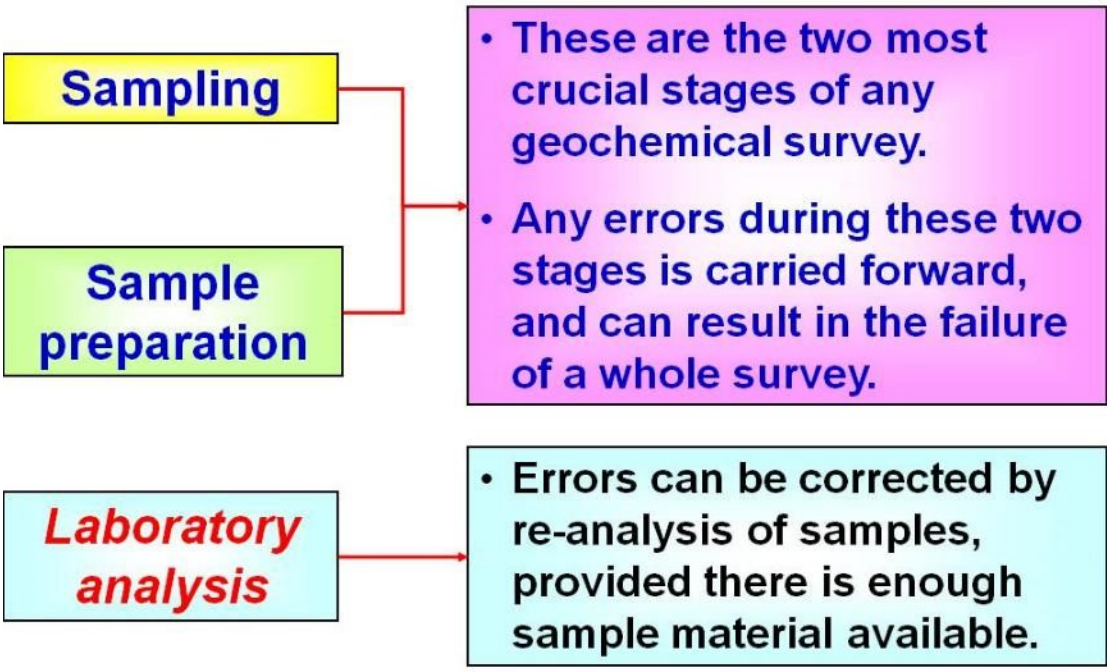


Figure A9. The sampling and sample preparation stages are crucial stages of any geochemical survey.

A4. SAMPLING SCHEME: SHENYANG GEOLOGICAL SURVEY

According to the IGCP proposal, Shenyang Geological Survey is already conducting a geochemical survey on the Black Soil of North-east China. It is stated that the 1:250,000 grid based geochemical survey covering an area of about 300,000 km^2 will be completed within the next five years.

The sampling method used is collecting surface soil from a depth of 0-20 cm at a density of 1 site/1 km^2, and deep soil samples from the depth range of 150-200 cm at a density of 1 site/4 km^2.

It is further stated that surface soil samples within a 4 km^2 grid and deep soil samples within a 16 km^2 grid are mixed to make a composite sample for laboratory chemical analysis.

Comments: *Taking depth related samples without consideration of soil horizons is not an acceptable method, because each soil horizon has its own physico-chemical characteristics. Therefore, a soil horizon-based geochemical survey must be contacted. Compositing the original field soil samples to make an artificial laboratory sample again it is NOT AN INTERNATIONALLY ACCEPTED METHOD, because the integrity, uniqueness and representativeness of the original soil sample is lost.*

Figure A10 shows a non-significant lead (Pb) anomaly in soil. *Why is it non-significant?* Taking soil samples from a constant depth range, resulted in sampling the A- and B-horizons, two horizons with different physico-chemical properties, while the aim was to sample the B-horizon. The A-horizon of soil is enriched in organic material, which has a tendency to concentrate metals, forming usually organo-metallic complexes. Lead in the B-horizon soil samples has low concentrations, which give an impression that these values belong to the background variation. Lead values begin to rise as soon as soil samples are collected from the organic rich topsoil, and the highest values are found at points where the A-horizon is thicker. Therefore, this enrichment of Pb appears to be due to soil forming processes, and the collection of samples from different soil horizons, and bears no obvious relation to the B-soil horizon from which all the samples should have been collected.

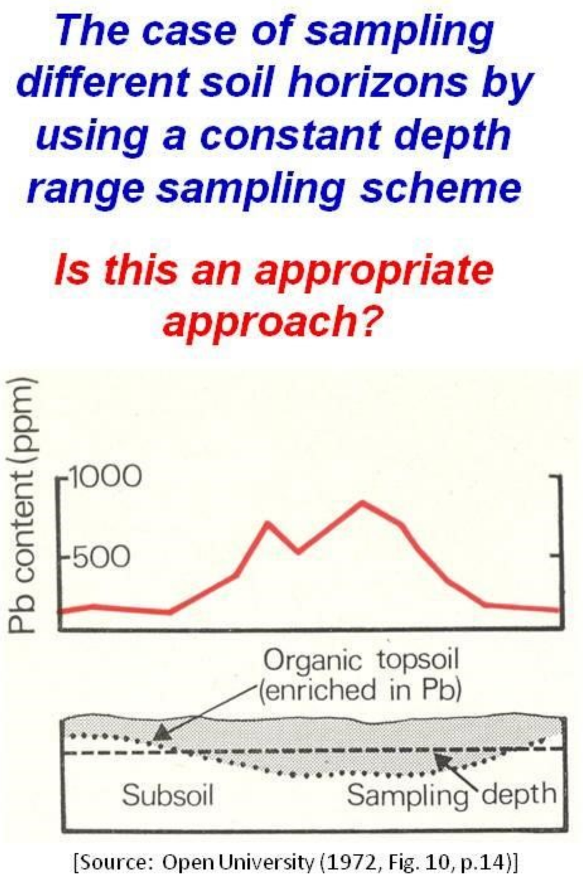


Figure A10. Soil sampling at constant depth, and Pb concentration in the collected samples.

The cross-section of Figure A11 shows the variation of aqua regia extractable Cu in samples from different soil horizons, and even within the B-horizon. Thus, suggesting that one has to be very careful in the collection of soil samples.

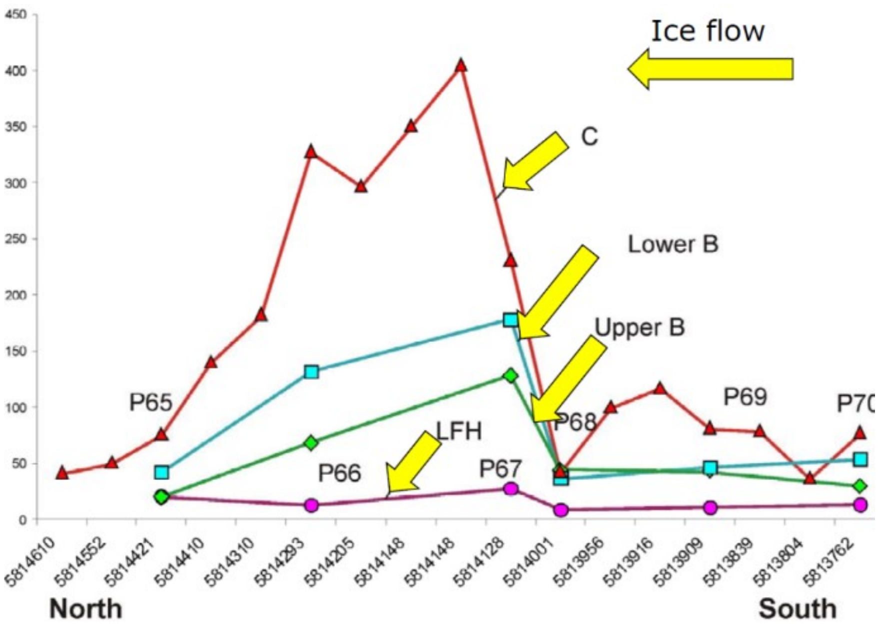


Figure A11. Variation of aqua regia extractable Cu in samples from different soil horizons (Source: Lett, 2009, Slide 24).

A5. COMPOSITING FIELD SAMPLES TO MAKE AN ARTIFICIAL LABORATORY SAMPLE

Let us now use the Socratian approach to examine the validity of compositing natural field soil samples to make an artificial laboratory sample (Socrates lived in Athens, Hellas, c. 470-399 BC).

"Socratic questioning (or Socratic maieutics) is disciplined questioning that can be used to pursue thought in many directions and for many purposes, including: to explore complex ideas, to get to the truth of things, to open up issues and problems, to uncover assumptions, to analyse concepts, to distinguish what we know from what we do not know, to follow out logical implications of thought or to control the discussion. The key to distinguishing Socratic questioning from questioning in a natural way is that Socratic questioning is systematic, disciplined, deep and usually focuses on fundamental concepts, principles, theories, issues or problems" (Source: https://en.wikipedia.org/wiki/Socratic_questioning). It is in depth questioning and irritating for the participants in the discussion, but very educational!

Question 1: What is the overall purpose of a geochemical survey?

The overall purpose of a geochemical survey is to collect and analyse systematically samples of rock, soil, stream sediment, floodplain sediment, water or plants in order to understand the chemical make-up of these samples, to enhance our understanding of the sources and mobilities of chemical substances, and to present their spatial distribution on a map.

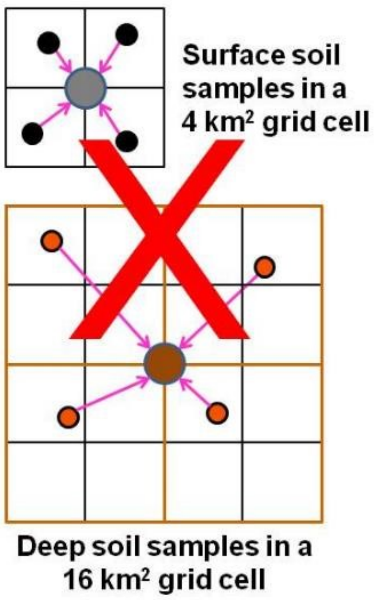
Question 2: Does an artificial laboratory composite sample satisfy the overall purpose of a geochemical survey?

Question 3: What happens to 4 natural field soil samples collected from either a 4 or a 16 km^2 grid cell, when they are composited to make a new artificial laboratory sample?

Equal weight proportions are taken from each soil sample to make the laboratory composite sample.

The new artificial laboratory composite soil sample is given the central point coordinates of the 2 x 2 and 4 x 4 km grid cell (4 km^2 and 16 km^2).

This procedure destroys the integrity, uniqueness, and representativeness of the individual field soil sample.



Question 4: What are the soil-forming factors?

According to Hans Jenny (1941, 1994), the independent variables or soil forming factors may be represented by the following equation:

s = f(cl, o, r, p, t, ...)

Where:

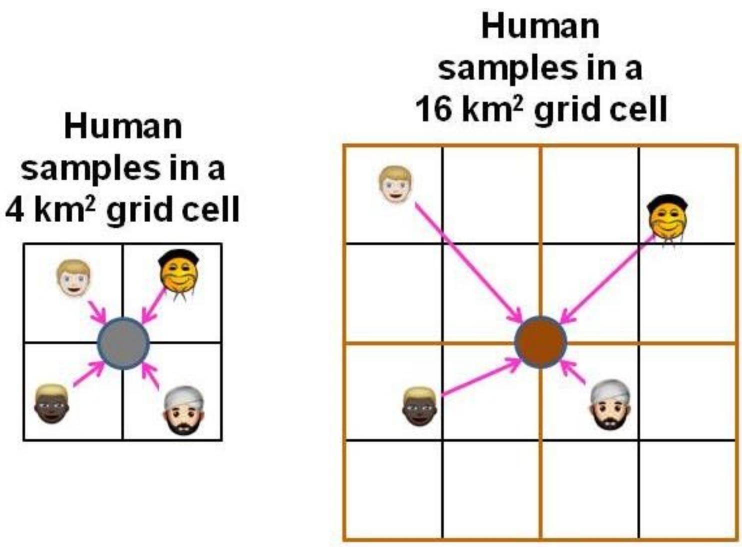
s = soil properties;
cl = climate;
o = potential biota (organisms);
r = topography (relief);
p = parent material;
t = time;
… = other factors including human interferences.

Question 5: What characterises a sample?

Taking into account Jenny's equation of soil forming factors, it can be concluded that each soil sample is unique with respect to the way it has been formed, and representative of its geographical location.

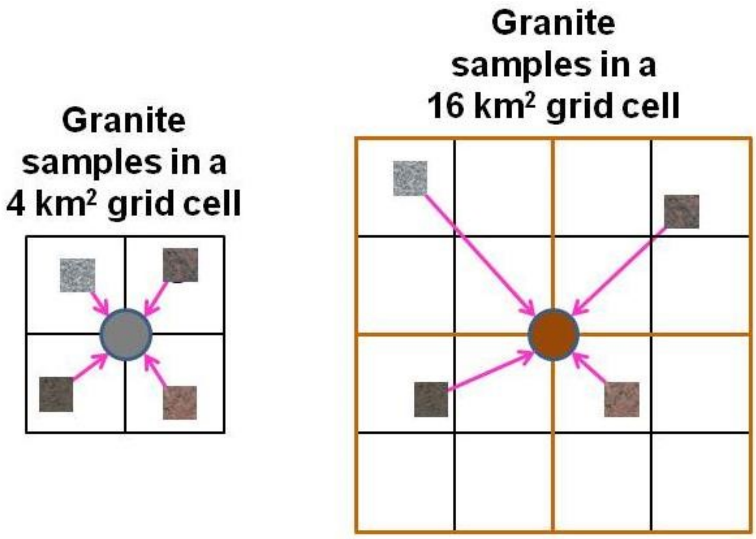
Let us now for argument's sake use 4 human beings of completely different races, each living on their own 1 or 16 km^2 plot of land. It is a far-fetched example, but is the only way to prove that it is quite illogical and improper, to say the least, to composite natural samples, and to destroy, in fact, their integrity, uniqueness, and representativeness.

Question 6: Can you make a composite laboratory sample from 4 completely different individual human beings?



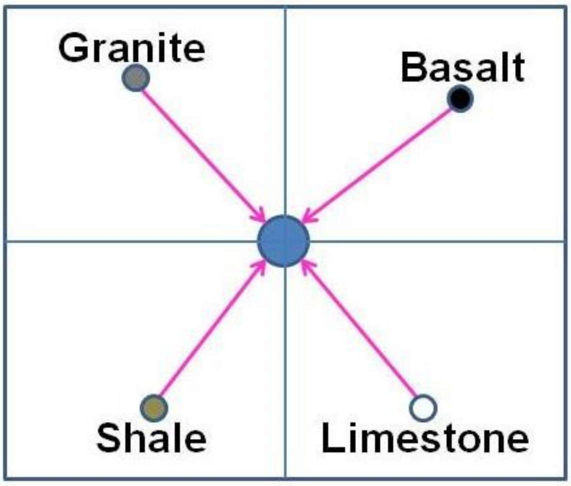
You are sampling 4 properties, each having a different granite type.

Question 7: Is it appropriate and logical to make a composite laboratory sample from the 4 different granite types?



You are sampling 4 properties, each having a different dominant parent rock type.

Question 8: Is it appropriate and logical to make a composite laboratory sample from different rock types?



REMEMBER that each rock type has a completely different preferential trace element composition.

Basaltic or mafic rocks are enriched in copper (Cu), manganese (Mn), scandium (Sc), strontium (Sr), titanium (Ti), vanadium (V) and zinc (Zn).

Granite is enriched in barium (Ba), Cerium (Ce), chlorine (Cl), fluorine (F), hafnium (Hf), lanthanum (La), lithium (Li), molybdenum (Mo), lead (Pb), rubidium (Rb), tantalum (Ta), thorium (Th), thallium (Tl), uranium (U), yttrium (Y) and zirconium (Zr).

Shale is preferably enriched in arsenic (As), boron (B), barium (Ba), beryllium (Be), cerium (Ce), chlorine (Cl), cobalt (Co), chromium (Cr), copper (Cu), fluorine (F), gallium (Ga), lithium (Li), lead (Pb), rubidium (Rb), scandium (Sc), titanium (Ti), vanadium (V), zinc (Zn), zirconium (Zr) and the Rare Earth Elements.

Limestone is preferably enriched in silver (Ag), bromine (Br), manganese (Mn), and strontium (Sr).

If the answers to asked questions are definitely and emphatically NO! It proves beyond any doubt that compositing natural samples cannot stand critical scientific scrutiny.

Then STOP compositing natural soil samples to make a laboratory sample for analysis.

As the sole purpose of compositing individual soil samples is to reduce the laboratory cost, then design a sampling scheme with fewer samples.

Remember that each natural soil sample is unique, and by compositing the 4 individual samples, collected from 4 different sites from either 2 x 2 or 4 x 4 km grid cells, an artificial laboratory sample is made, which has no longer any relationship to the original individual soil samples. The integrity, uniqueness, and representativeness of the individual natural soil sample are completely lost.

The samples of the FOREGS Geochemical Mapping of Europe (Salminen et al., 2005) were also analysed at the Institute of Geophysical and Geochemical Exploration (Langfang, Hebei Province).

To our surprise, upon receiving the analytical results, it was realised that the samples in each GRN grid cell were composited to make a laboratory analytical sample.

When we asked the reason for analysing laboratory composite samples, instead of the actual samples as agreed, we were informed that this was done because of cost, and the individual samples are going to be analysed at a later date, but they have never been analysed.

Hence, very valuable field samples were destroyed for the sake of reducing laboratory costs.

This destruction of the FOREGS soil samples can be seen in the following Sn distribution maps in topsoil and subsoil. The original data set of 848 topsoil and 788 subsoil samples was reduced to 198 and 192 composite samples, respectively. As expected the patterns of the Chinese composite samples are generalised, and do not have the detailed information of the original FOREGS geochemical maps (Figures A11, A12). Of course, another serious drawback of the Chinese soil sample composites is that the variable-size dots cannot be plotted, because the composite samples have artificial coordinates, i.e., the coordinates of the central point of the 160 x 160 km GTN grid cell.

In order to understand the ludicrous situation of sample compositing, geochemical distribution maps of Sn were plotted using the same percentiles for the classes, i.e., topsoil: Figures A11*c,d* and subsoil: Figures A12*c,d*.

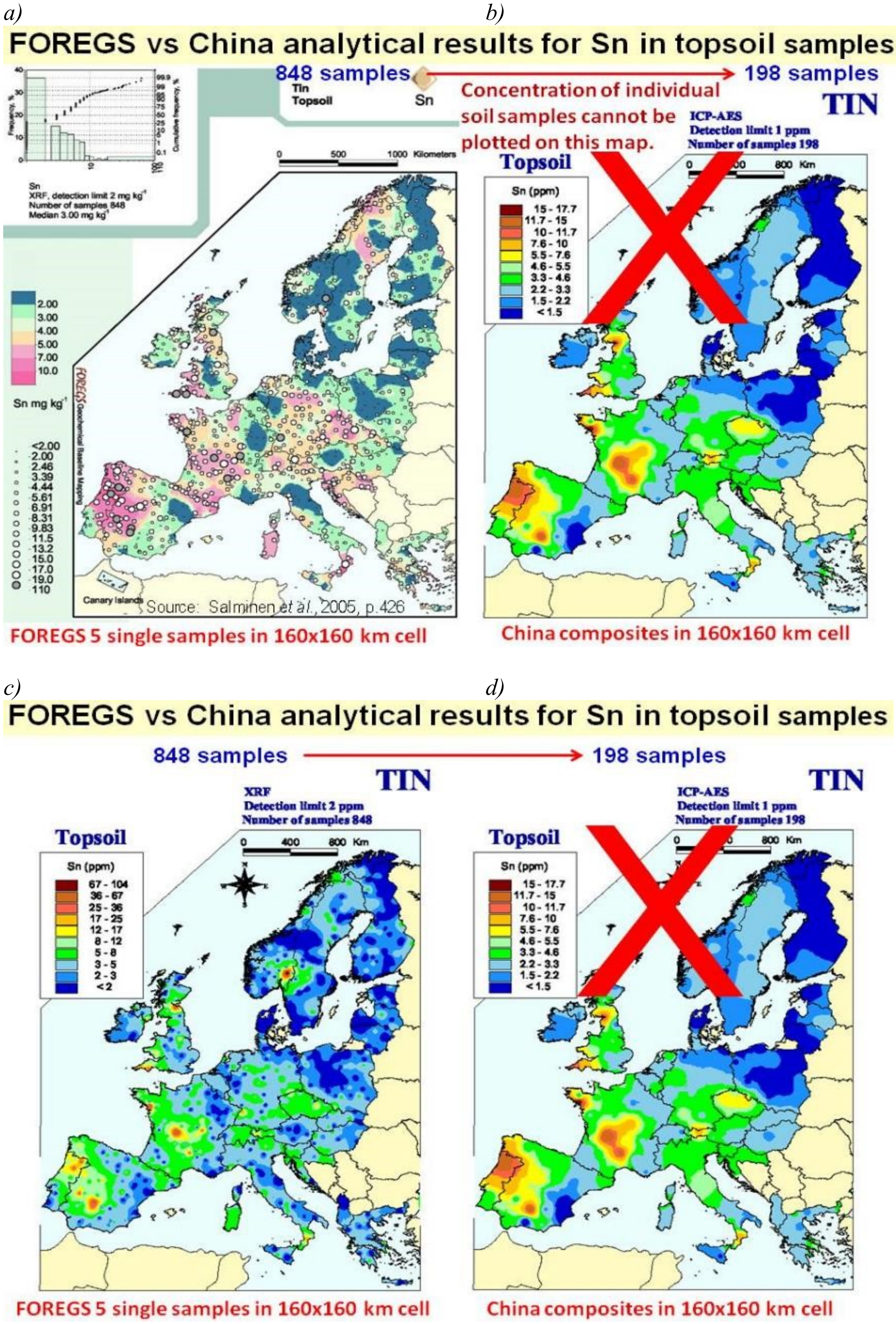
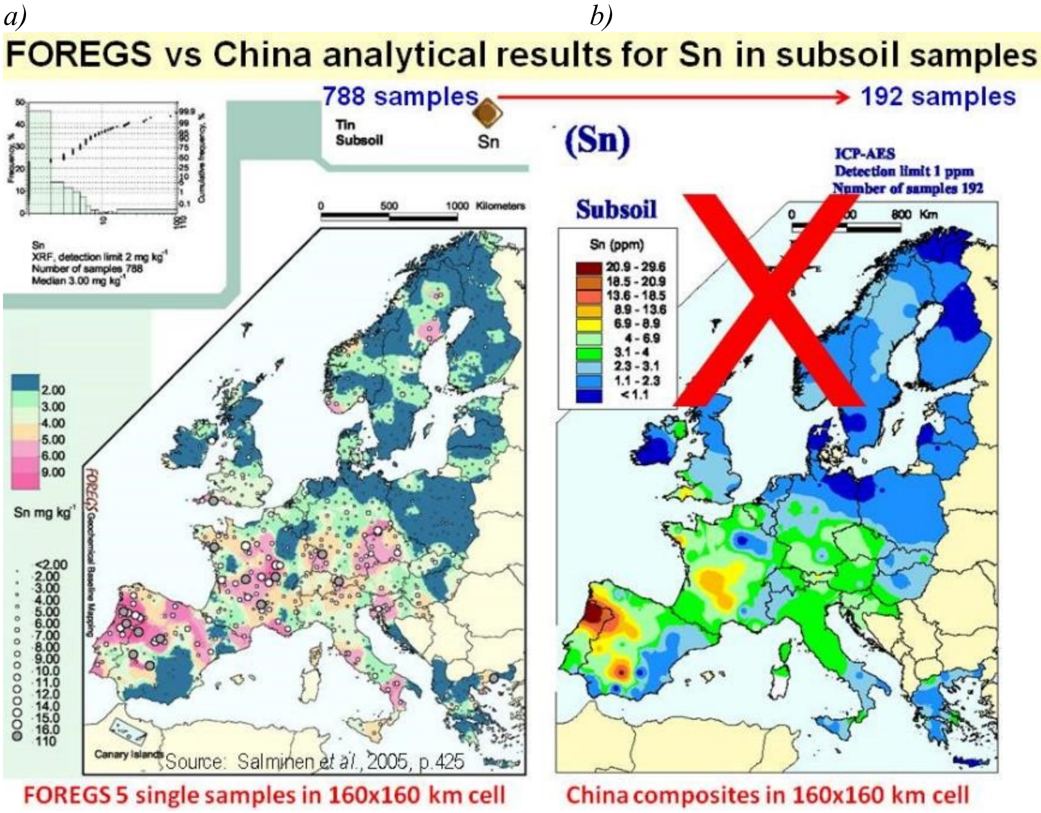


Figure A11. Comparison of FOREGS and Chinese analytical results for Sn in topsoil samples: a) FOREGS atlas map with all 848 samples used in the interpolation, and variable-size dots showing the Sn concentration at each site; b) China composite sample results; c) and d) FOREGS and Chinese Sn results in topsoil samples, respectively, using the same percentiles for the concentration classes.

a) *b)*



c) *d)*

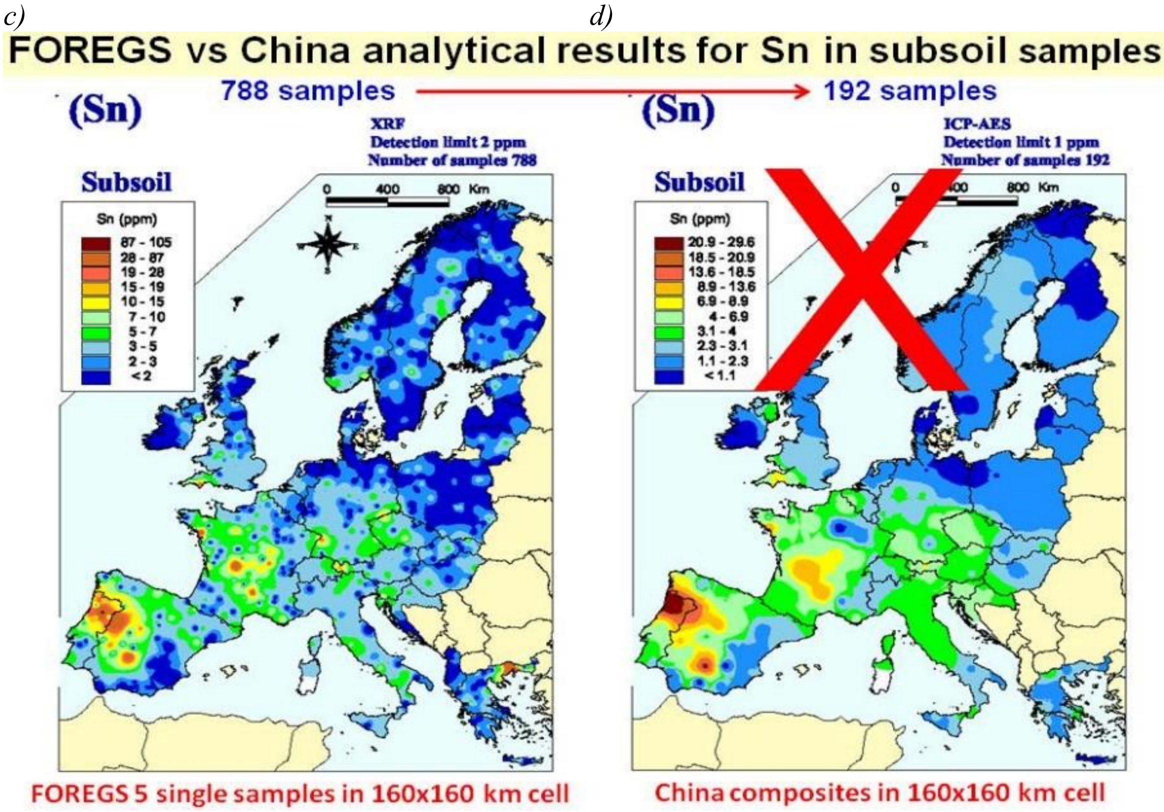


Figure A12. Comparison of FOREGS and Chinese analytical results for Sn in subsoil samples: a) FOREGS atlas map with all 788 samples used in the interpolation; b) China composite sample results; c) and d) FOREGS and Chinese Sn results in subsoil samples, respectively, using the same percentiles for the concentration classes.

A6. ADDITIONAL COMMENTS ON IGCP PROJECT PROPOSAL

A6.1. Comments on Objectives 1 and 6

It is assumed that these particular objectives concern the compilation of existing geochemical data. One has to be very careful in the use of such compiled geochemical databases, where the sampling, sample preparation, and analytical methods are different. Such data are incompatible, and should NEVER be compiled in the same database and then presented on the same map.

An important conclusion of the "Blue Book" is that although there are many national geochemical surveys, a global geochemical baseline overview cannot be presented with existing data, because of inherent incompatibility among the data sets. *Hence, the 1995 proposal for the development of a Global Geochemical Baseline database states that all samples should be collected, prepared, and analysed by exactly the same methods.*

Example: Data produced in different continental-scale geochemical surveys, using different sampling, sample preparation and analytical methods MUST NEVER be placed in the same database and produce maps like the one below (Figure A13), as wrong conclusions can be made.

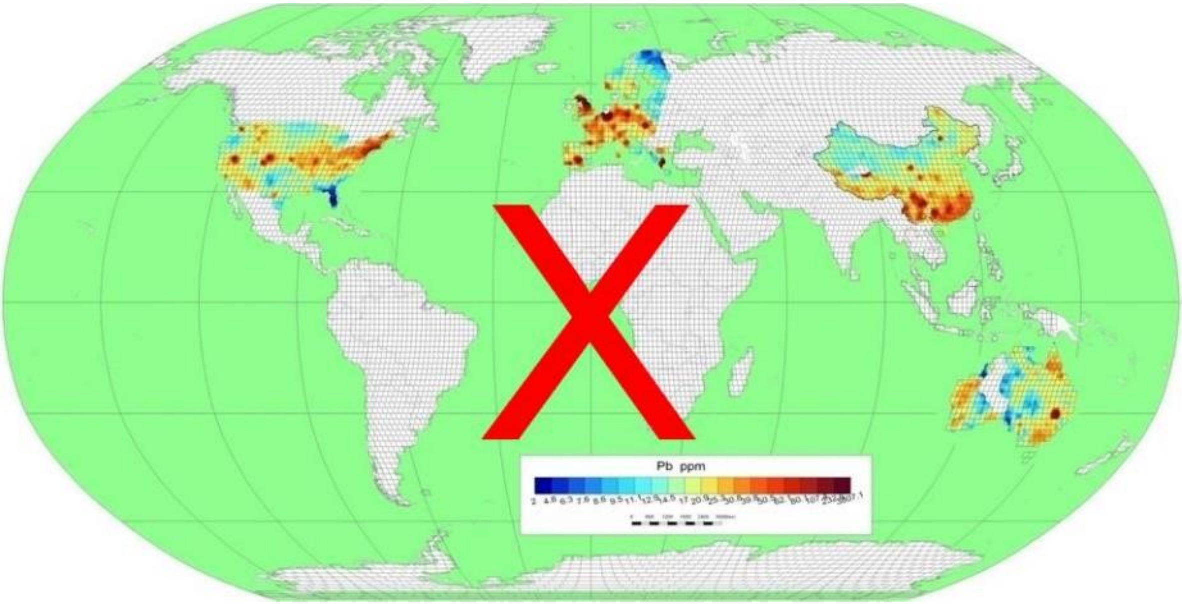


Figure A13. Global geochemical map of Pb showing the results of 4 continental-scale projects: a) FOREGS Geochemical Atlas; b) Australia geochemical atlas; c) China geochemical atlas; and d) United States of America Geochemical Atlas (Source: Xueqiu Wang's presentation entitled "Initiative for the International Scientific Project on Mapping the Chemical Earth", *Opening Ceremony of UNESCO International Centre on Global-Scale Geochemistry, Langfang, China, May 2016).*

A6.2. Comments on 8.4. Workplan and 8.5

Collection and integration of basic data, starting in 2018 and continuing until 2020, and modelling.

(a) 1:250,000 geochemical survey of Northeast China: As far as we know the analytical results of this survey are on laboratory composite samples. Hence, it is not an internationally acceptable high quality data set.

(b) USGS Soil geochemical and mineralogical survey of conterminous United States, and

(c) EuroGeoSurveys GEMAS data set.

Although (b) and (c) are high quality geochemical data sets, they are incompatible, because of the different methodologies used for their development. Therefore, they should NEVER be included in the same database and presented on the same map.

Caution: Modelling with incompatible geochemical data sets is unacceptable practice, and the punch line of computer database development is very appropriate here: "Rubbish in, Rubbish out". A European Research Organisation has carried out such modelling, and the results have been strongly criticised.

A6.3. Comments on Critical Zone Observatory (Objective 6)

To establish a space-air-ground integrated observation system using Remote Sensing and geochemistry. The proposal is to use the Global Terrestrial Network grid cells of 160 x 160 km (25,600 km^2), and the five random sites in order to establish the network of observation sites.

The entire area of 9.2 million km^2 can be covered by 360 grid cells of 160 x 160 km. In total, 3600 samples (i.e., 360 grid cells x 5 sample sites x 2 samples/site) + 360 duplicate field samples.

Therefore, in order to establish a "solid foundation" for Black Soil Critical Zone research the methodology must be harmonised and strictly followed by all participating countries.

A6.4. Sampling Design of Mollisols Soil Survey

The sampling design of mollisols depends on the objectives of the investigation. Hence, we need to agree on the objectives.

In agricultural areas, the farmer would definitely like to know the chemical composition of soil in her/his property. In such a case, the sampling density at the property level is quite dense.

As Mollisols are intensively cultivated, then the ploughed surface soil will most likely be sampled. The normal ploughing depth rarely exceeds 20 cm. However, farmers perform deep ploughing occasionally, and this reaches a depth slightly greater than 50 cm.

The objective is then to map the chemical quality of Mollisols in a cost-effective manner, and to monitor their quality.

A7. SAMPLING SCHEME

There are at the moment the following field methods manuals (Figure A14):

1. "Blue Book" provides general guidelines (Darnley et al., 1995);
2. "Green Book" (FOREGS Field Manual) – residual soil (Salminen et al., 1998);
3. "GEMAS" project field manual – agricultural Ap and grazing land soil (EuroGeoSurveys Geochemistry Working Group, 2008), and
4. North American Soil sampling manual (Smith et al., 2013).

The North American Soil sampling manual (Smith et al., 2013) appears to be the most suitable for the BASGES project, in combination with the Global Terrestrial Network grid cells of 160 x 160 km (Figure A15). Figure A16 shows the GTN sampling design and its development from the continental- to the local-scale.

Figure A14. Global geochemical sampling manuals.

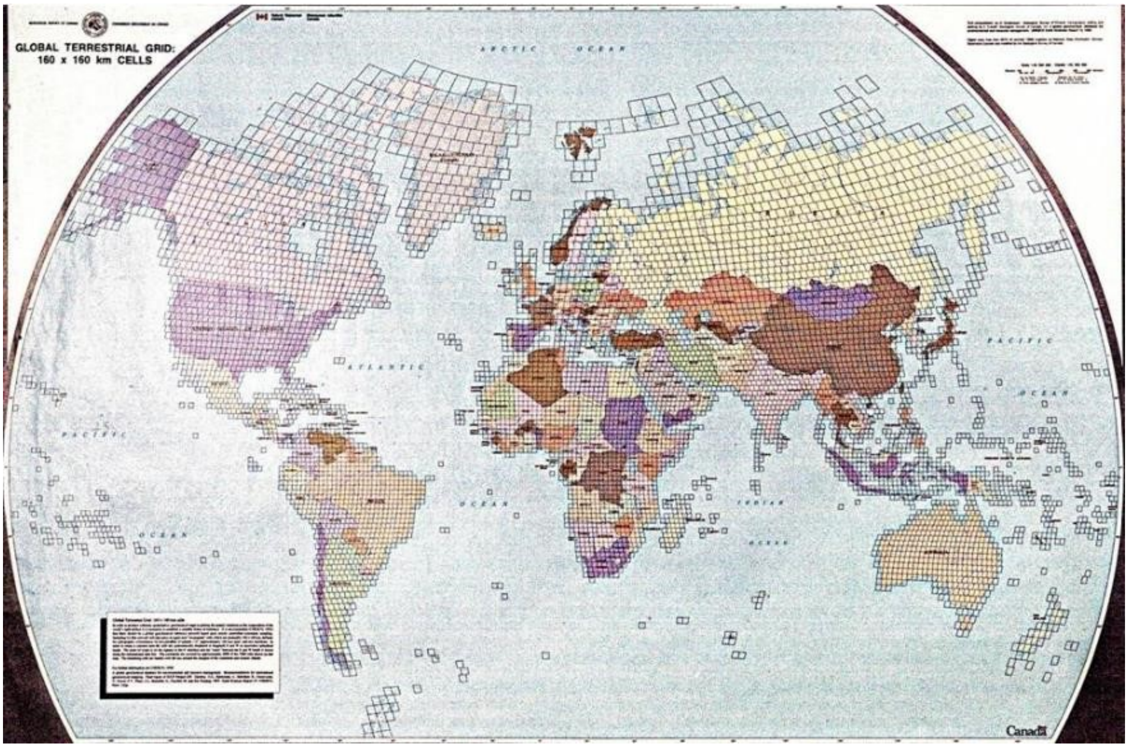
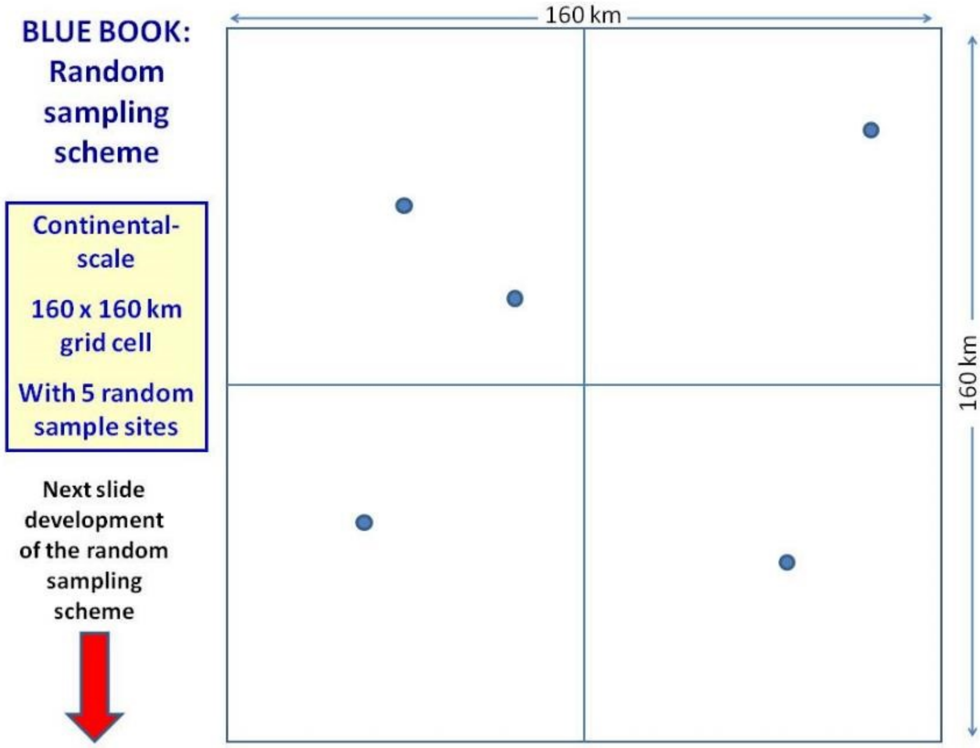


Figure A15. Global Terrestrial Network (GTN) grid cells (n=5000) of 160 x 160 km (Darnley et al., 1995).

a)



b)

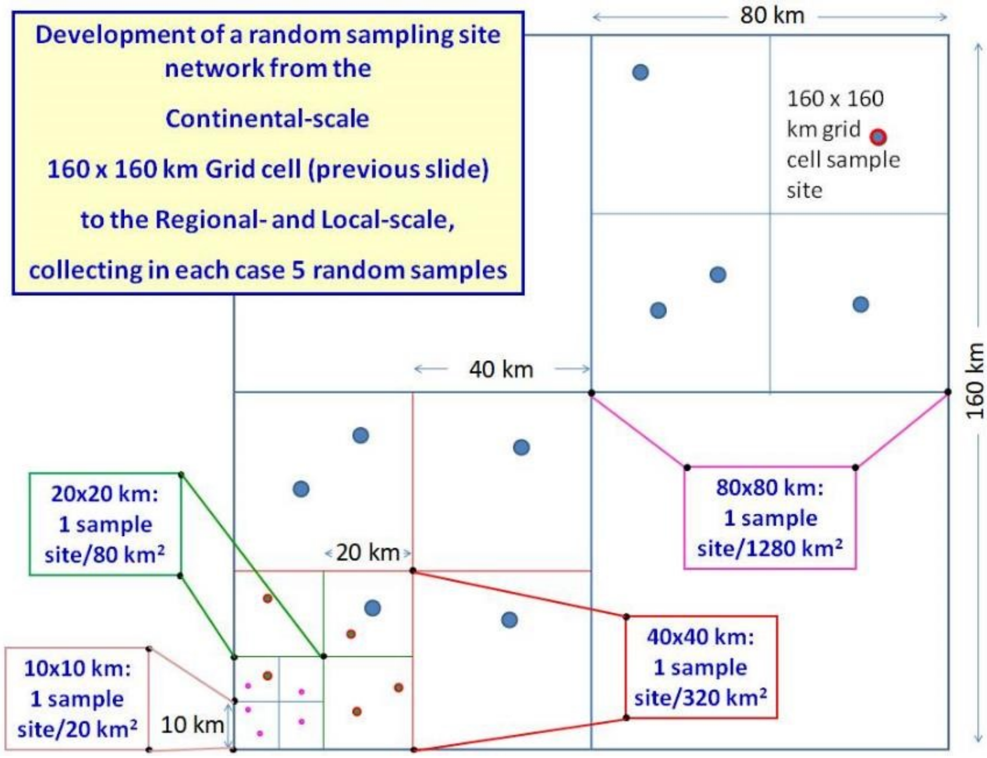


Figure A16. a) Continental-scale 160 x 160 km grid cell subdivided into 4 quadrants of 80 x 80 km with 5 random sample sites; and b) Development of a random sampling site network from the continental- to the local-scale.

Hence, the proposal is to use the Global Geochemical Baselines Terrestrial Network (GTN) grid at any agreed sampling density, and to collect 5 random samples within the dimensions of the agreed grid cells.

The soil sampling must be horizon based.

'A' soil horizon sampling: As the interest in Mollisols is the A soil horizon, the recommendation is to sample the entire thickness of the A horizon from a single pit. The reason for this recommendation is that by looking at the soil colour of the different mollisols profiles there is obvious chemical variation even within the 20 cm thick sections. Hence, by sampling the entire thickness of the A soil horizon, the average chemical composition is obtained.

Alternatively: To sample from a single pit the Ap (ploughed) horizon down to a depth of 20 cm.

'C' soil horizon sampling: Sampling the C soil horizon may pose problems at many locations, because it can be quite deep in Mollisols.

Our recommendation is that a maximum thickness of 20 cm of the C soil horizon should be sampled, starting from the boundary with the B horizon. If the C horizon is <20 cm, then this section should be sampled. In the case where the C horizon is below 200 cm, then the bottom 20 cm should be sampled, i.e., 180-200 cm, and always from the same horizon.

A7.1. Field Soil Composites versus Single Pit Soil Sampling

With respect to field composite soil samples, in our experience, it is a waste of time and effort to collect composite field soil samples. Hence, it is strongly recommended to collect soil samples from a single pit (Figure A17).

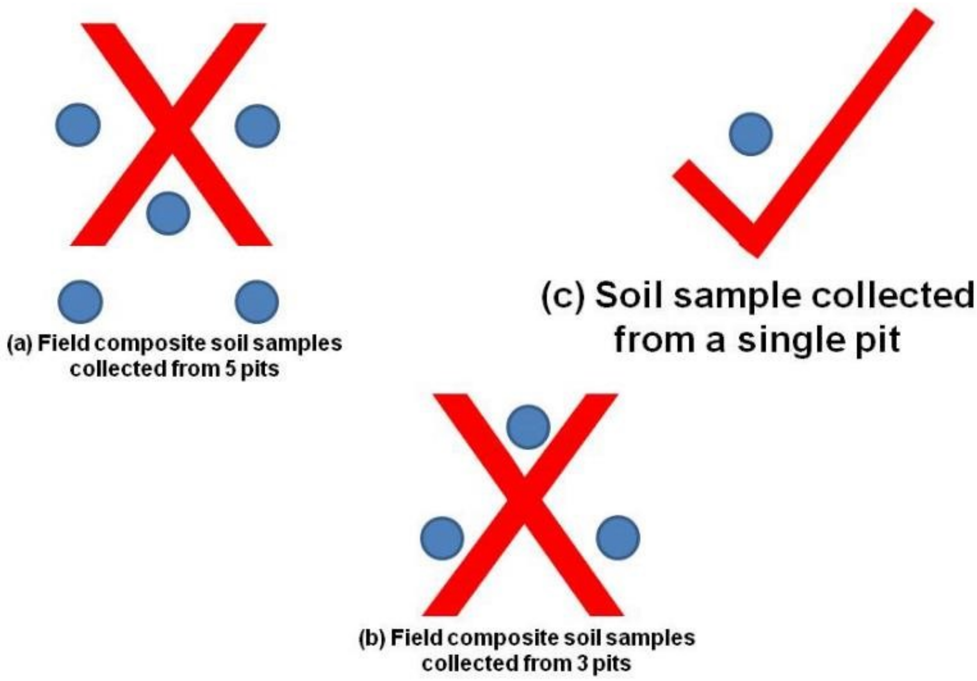


Figure A17. Field composite soil samples from (a) 5 or (b) 3 pits are a waste of time and effort. It is strongly recommended to collect soil samples from (c) a single pit.

A7.2. Soil Sampling Equipment, Soil Sampling, Sample Packing, and Photographic Documentation

Figure A18 shows the soil sampling equipment, and that unpainted or stainless steel equipment must be used, and preferably a white or colourless white scoop. Ideally, all the sample-packing materials should be bought centrally and distributed to all participating countries.

Figure A18. Soil sampling equipment.

Figure A19 shows the soil sampling packing equipment, and sample packing, as used in the EuroGeoSurveys' GEMAS project.

Figure A19. Soil sampling packing equipment, and sample packing.

Figure A20 shows the GEMAS agricultural soil sampling and packing, recording of site coordinates with a GPS and photograph-taking scheme.

Figure A20. GEMAS project sampling scheme, and sample packing, and order of photographic documentation.

Figure A21 shows the Hellenic variation of the GEMAS agricultural soil photograph taking with addition of a general and site-specific Google Earth image.

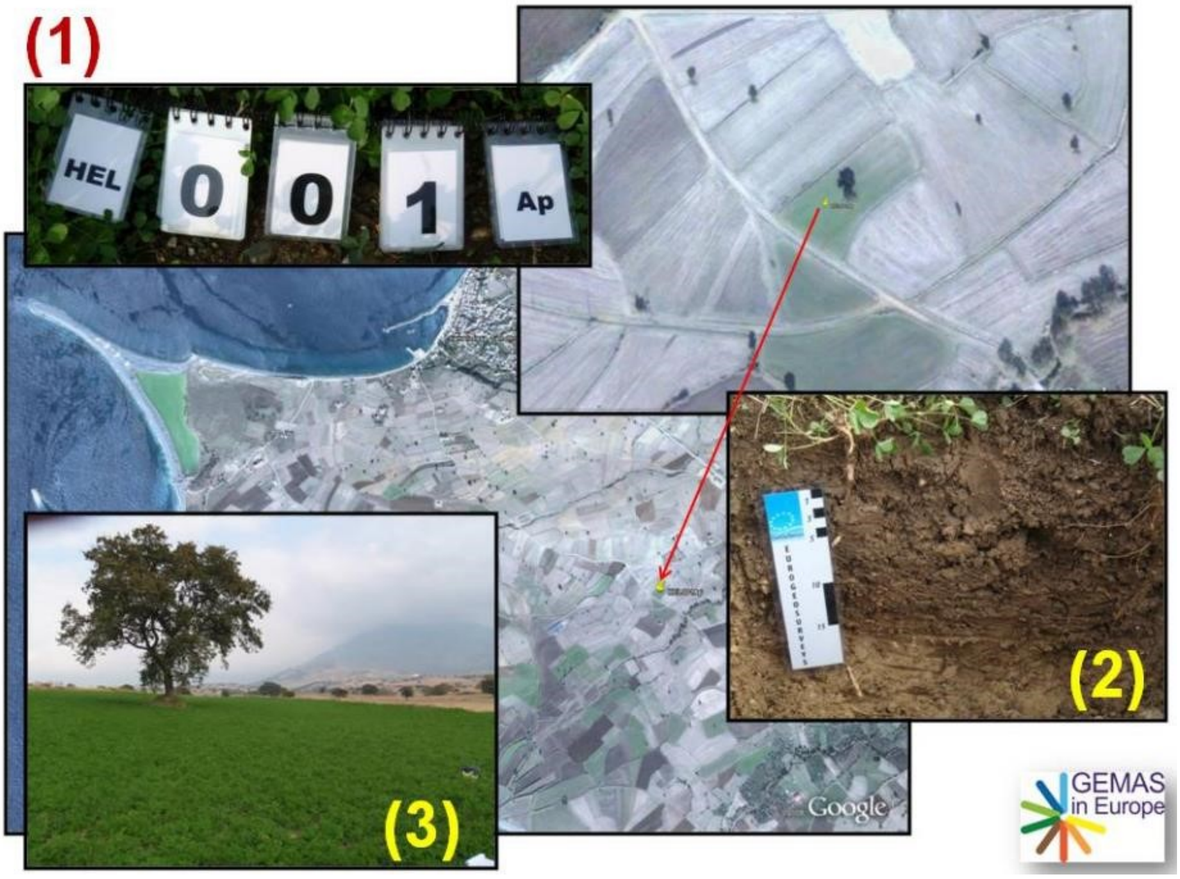


Figure A21. Hellenic GEMAS photographic documentation.

Recording of field observations

Before leaving the sampling site, the field observations sheet is completed (Figure A22), the sample position marked on the topographical map, and the GPS coordinates recorded. In this case, the FOREGS soil sampling field observations sheet is presented, because it records observations for both top- and sub-soil. A similar simplified field observations sheet will be designed for the BASGES project.

Figure A22 shows the soil field observations sheet used in the FOREGS Geochemical Baseline programme (Salminen et al., 1998).

FOREGS GEOCHEMICAL BASELINE PROGRAMME **SOIL**

TOP SOIL ID ________ Date ________ Sampler ________
SUBSOIL ID ________ Country ________
Organisation ________
GTN cell coordinator if different from above ________

SAMPLE SITE LOCATION REGION ________ MAP SHEET ________
COORDINATES **(Decimal degrees mandatory)**
National grid Easting ________ Northing ________
Decimal degrees Longitude ________ Latitude ________ Datum ________
Altitude (m) ________

SITE DESCRIPTION
Landscape / topography ________
Land use
□ Agriculture, specify crop ________
□ Pasture, grassland, fallow field
□ Forest: □ Deciduous □ Coniferous □ Mixed
□ Wetland
□ Non-cultivated, moorland etc.
□ Other, specify ________
Bedrock lithology ________ Outcrops □ Yes, specify ________
□ No outcrops
Type of overburden ________

NUMBER OF SUBSITES ________
SOIL TYPE (FAO classification or local name) ________
Ploughing depth (cm) ________
Subsoil, specify soil horizon ________
Sampling interval (cm): Topsoil ________ Subsoil ________
Depth of groundwater table (cm) ________

ABUNDANCE OF SOIL CLASTS %	**TOP**	**SUB**	**TEXTURE**	**TOP**	**SUB**
0	□	□	sandy	□	□
0 - 2	□	□	sandy-loam	□	□
2 - 5	□	□	loamy	□	□
5 - 15	□	□	clayey-loam	□	□
15 - 40	□	□	clayey	□	□
40 - 80	□	□	clay	□	□
> 80	□	□			

SAMPLE HUMIDITY	**TOP**	**SUB**	**ORGANIC CONTENT**	**TOP**	**SUB**
wet	□	□	high	□	□
dry	□	□	low	□	□

Possible sources of contamination, specify ________

PHOTOS Film and photo ID
Landscape ________
Site ________

GAMMA-RADIATION Total ________ Th ________ U ________ K ________
Instrument ________

BALTIC SOIL SURVEY countries only: BSS sample ID ________ is used for this sample.
The BSS sample has already been sent to the NGU □ yes □ no, will be sent by ________

REMARKS

Salminen, R. et al. 1998. FOREGS geochemical mapping field manual. Geologian tutkimuskeskus, Opas 47 - *Geological Survey of Finland, Guide 47*. Espoo. Appendix. Photocopying of this page permitted.

Figure A22. An example of a field observations recording sheet.

A8. SAMPLE PREPARATION

Ideally, all BASGES soil samples should be prepared in the same laboratory. A possible soil sample preparation scheme is shown in Figure A23.

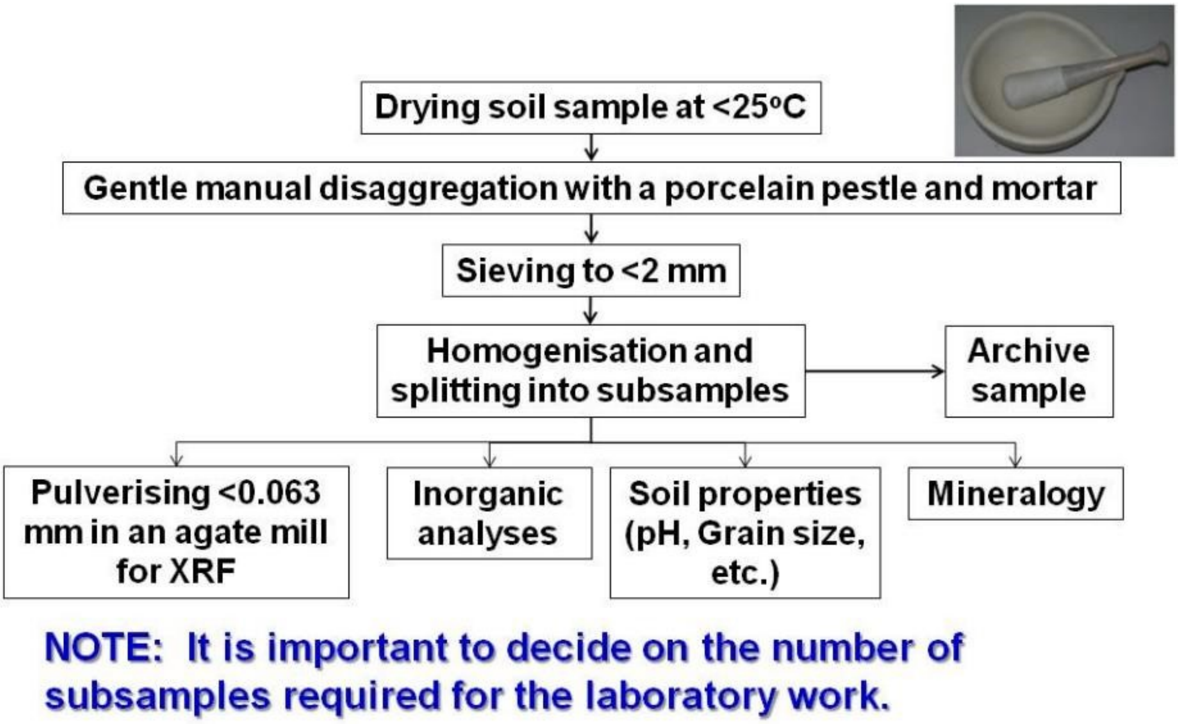


Figure A23. Soil sample preparation scheme.

Depending on the equipment used, minor contamination of soil samples is expected:

- Carbon steel (<0.2% Fe, no base metals)
- Hardened steel (<0.2% Fe, low Mn, Ni, Cu, Cr, Co)
- Chrome steel (up to 200 mg/kg Cr, <0.2% Fe, traces Mn, Cu, Co)
- Tungsten carbide (W, Co)
- Agate (Si)

A9. RANDOMISATION OF SAMPLES AND INSERTION OF QUALITY CONTROL SAMPLES

A9.1. Randomisation of Samples

Randomisation of samples is a necessary procedure in a geochemical survey to locate systematic errors introduced during sample preparation and analysis. Some of these systematic errors are (Plant, 1973; Fletcher, 1981, 1986):

- Contamination of uncontaminated samples by contaminated samples during sieving;
- Within-batch contamination of samples from an external source during grinding and pulverisation, and
- During the analysis of samples in the laboratory, changes in the conditions may occur, namely weighing balance drifting, analytical instrumental drift, interferences, etc. Such changes are monitored by the analysis of reference or standard samples introduced in every batch of samples.

The greatest problem is to attempt to interpret data affected by such systematic errors, because of the inherent difficulty to distinguish between false and real geochemical patterns.

Randomisation of samples is the method devised by applied geochemists to remove any systematic relationship between order of analysis and geographical location (Plant, 1973; Plant et al., 1975; Thompson, 1983; Schermann, 1990; Darnley et al., 1995; Reimann et al., 2008, 2009, 2011, 2012; Demetriades et al., 2014; Demetriades & Birke, 2015a,b).

By randomisation of samples any systematic between batch variation in analytical level is transformed to increased analytical variability, meaning that any systematic errors are spread randomly over all the samples.

A9.2. Insertion of Control Reference Samples in the Randomised Batches

A sufficient number of control reference samples should be inserted in the randomised analytical batches, i.e., splits of project reference samples, international reference samples, and field duplicate samples.

The control reference samples are for detecting any between-batch variation. If such variations are identified, then the affected batches of samples should be submitted for re-analysis, and the new analytical results utilised, provided they are satisfactory according to fitness-for-purpose.

An additional advantage of sample randomisation is the concealing of project and international reference samples, and project replicate samples in the analytical batches and, thus, not recognised by the laboratory.

IMPORTANT NOTE: For planning purposes, the number of samples analysed by the laboratory each day must be known in order to arrange the number of control samples that will be inserted in each analytical batch of samples. This is very important information for the planning of the external quality control scheme.

Generation of sample numbers: During the planning of the geochemical survey, the independent quality control scheme, which depends to a certain extent on the number of samples the laboratory analyses per day, must be planned and installed.

Ideally, the total number of samples that will be collected during the geochemical survey should be randomised, taking into account the number of quality control samples that will be inserted, i.e., international standard/reference samples, project standards and splits of the routine and field duplicate samples.

Therefore, the samples are collected in a random order, and after preparation, they are placed in consecutive order, and quality control samples inserted.

In case the samples are not collected in a random order, then they will have to be randomised in the sample preparation laboratory, and new numbers given.

This is a very dangerous procedure, and should be carried out very carefully, and a record kept.

Upon receiving the analytical results, the original sample numbers must be inserted.

A9.3. Preparation of BASGES Reference Samples

It is recommended to prepare two large BASGES project Reference Samples (≈200 kg each).

A10. LABORATORY ANALYSIS

A10.1. Selection of Analytical Methods

- The analytical methods used must be sufficiently sensitive to allow detection of a wide range of determinands at below natural background levels.
- The analytical precision must be good, preferably significantly better than natural geochemical variation.
- The analytical accuracy must also be good, preferably even better than that achieved in most national geochemical surveys, and
- All data and other records pertaining to the analysis and testing must be fully documented and traceable.

Total element concentrations are most relevant for geochemical interpretation of data. For solid materials (soil and sediments), this means that the silicate matrix either needs to be fully decomposed by a hot mixed concentrated acid digestion before instrumental analysis, or a solid sampling technique, such as X-ray fluorescence (XRF) or Instrumental Neutron Activation Analysis (INAA) need to be used.

To address the needs of national and European level environmental authorities, information on leachable concentrations of the elements in soil and sediments is also considered important. In environmental chemistry, a slightly unscientific and non-specific term, 'near total' extraction method is often used to describe the maximum concentration of an element that can be liberated from a material in its natural environment. An aqua regia leach or digestion is normally used for simulating this characteristic in the laboratory. An unfortunate fact is that almost every laboratory has its own standard operating procedure for carrying out aqua regia leaching.

In addition, the samples must be analysed by a weak leach.

A10.2. Development of a Uniform and Homogeneous European Geochemical Database

For the development of a uniform and homogeneous geochemical analytical database, ALL samples of the same type were analysed at the SAME laboratory by exactly the SAME analytical method and for the SAME suite of chemical elements.

In addition, a strict quality control (QC) procedure was applied to ensure the generation of analytical data of high quality and integrity (i.e., field duplicate spits, and project standard). For environmental purposes, the produced analytical results should be legally defensible.

This is the only way to produce uniform and compatible geochemical databases across political boundaries, and to satisfy the conditions of the IUGS Global Geochemical Baselines project, and not only.

As an example, the samples collected for the FOREGS Geochemical Atlas of Europe project is mentioned. All the collected samples were analysed in nine laboratories of the European Geological Surveys for the same suite of elements by exactly the same analytical method.

A10.3. Important Points to Remember for the Development of a Uniform and Homogeneous Geochemical Database

In order to ensure data homogeneity, and to avoid any bias between laboratories or analytical methods, you MUST send all samples to the same laboratory, where they will be analysed by an agreed analytical method.

NEVER send samples from the same project to different laboratories for analysis, and expect that the results will be compatible.

NEVER COMPOSITE NATURAL SAMPLES IN THE LABORATORY: Each sample is unique and representative of the site that has been taken from. The integrity, uniqueness, and representativeness of each field sample are lost when making artificial samples in the laboratory by compositing.

A10.4. Important Condition

You must ask the laboratory not to censor element concentrations at its laboratory detection limit, but to provide you with all the analytical results, as reported by the instrument, even negative values.

You should estimate the practical detection limit of each element for your project.

A11. QUALITY CONTROL CHECK

'Quality', it is something that is being discussed from ancient to recent times. Already Aristotle (384-322 B.C.), the renown ancient Hellene philosopher considered 'quality' in his famous work 'Categories'. The Aristotelian philosophical approach demands a rational assessment of quality. Therefore, one can assume with good reason that it is not an easy topic to grasp and apply. The problem with the attribute of 'quality' is that it is somewhat subjective and may thus be understood differently by different people. In modern times, it is most often defined as *'fitness-for-purpose'*.

A11.1. Quality Control Issues

Quality control starts in the field, and continues in the laboratory during sample preparation and analysis.

- Field duplicate samples: Depending on the total number of samples that will be taken in a geochemical project, field duplicate samples should be collected at a rate of 5% to 10%.
- Laboratory:
  - Analysis of field duplicate splits using a balanced analysis of variance (ANOVA) design;
  - Internal (including international standards) and External reference materials should be analysed at regular intervals (between 1 and 2%, depending on the method) to monitor long-term stability.

Upon receipt of the analytical results, the following checks must be made:

- Analytical blanks
- Internal laboratory standards
- International standards
- External reference materials (i.e., BASGES project standards)
- Laboratory replicate analyses
- Duplicate field analyses

A11.2. Plotting Sequence Diagrams

Sequence diagrams should be plotted according to the consecutive number order the samples were analysed. The plotted analytical results are expected to display a random variation over the whole range. Any significant time trends, breaks, carry over or memory effects, or any other peculiarities related to location of the samples in the analytical sample batches would be detected.

Figure A24 shows a sequence plot of As, and the expected random variation is disrupted by two outlying values of sample KAS140 and its duplicate split KAS140A1. In this case, the outlying value of the routine field sample KAS140 is verified by its duplicate split in the random order of analysis of the project samples.

Figure A25 displays a sequence plot of Cr, and again one outliner, KAS117, disturbs the expected random variation. This particular lake sediment sample is near the outcropping ophiolite mass. Hence, there is an explanation for the outlying Cr value.

If the outlying values cannot be explained, then the analytical batch or batches should be reanalysed.

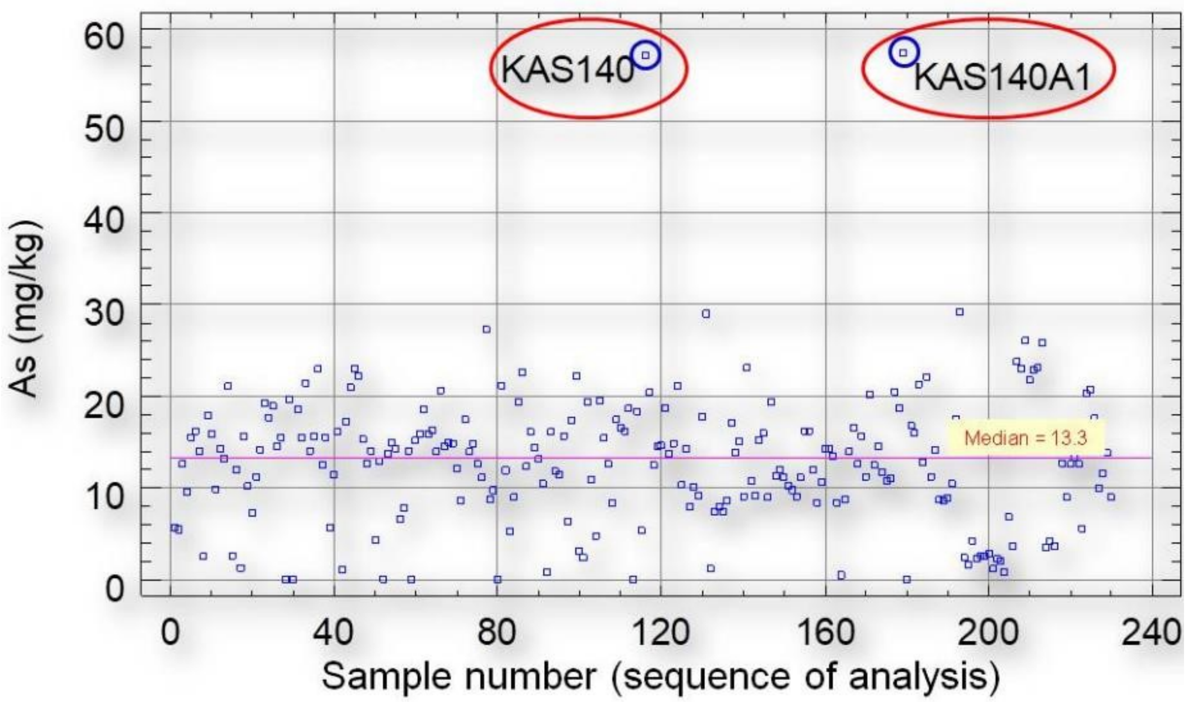


Figure A24. Sample number (sequence of analysis) plotted against the analytical results of As.

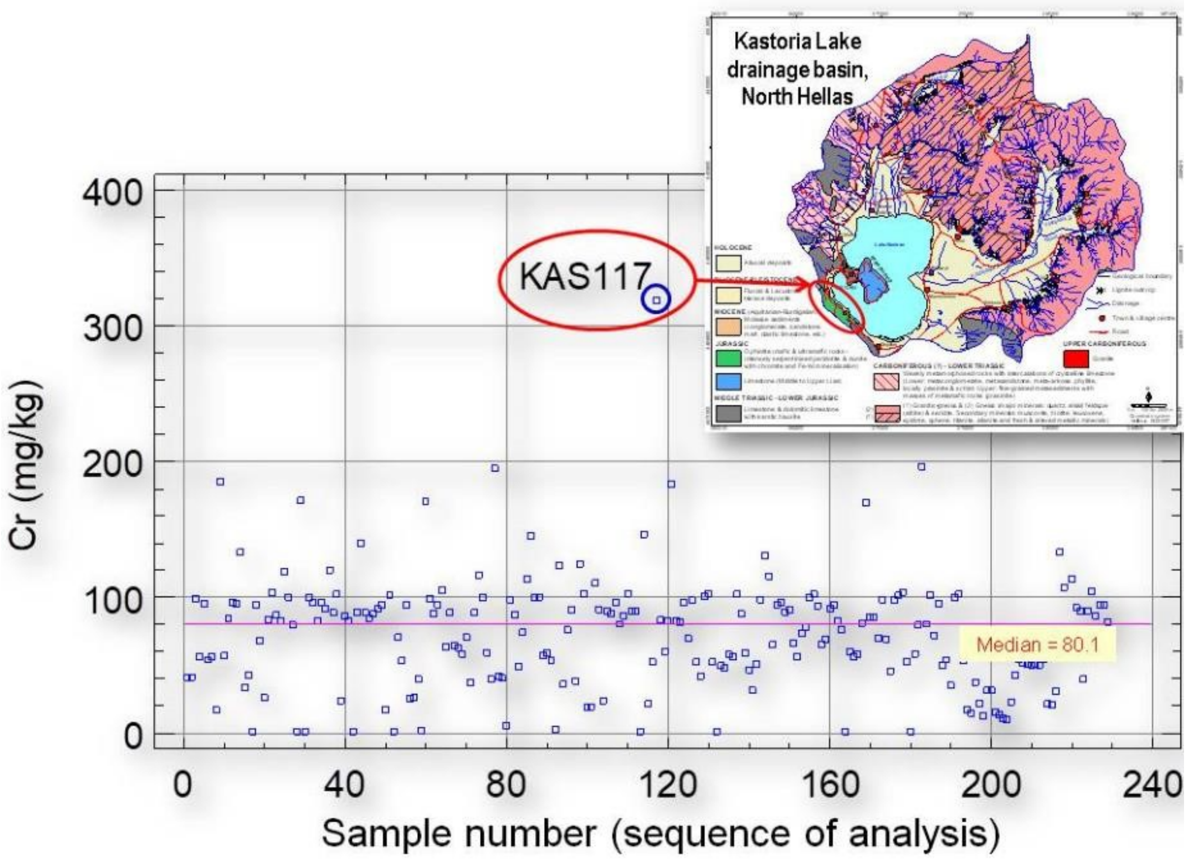
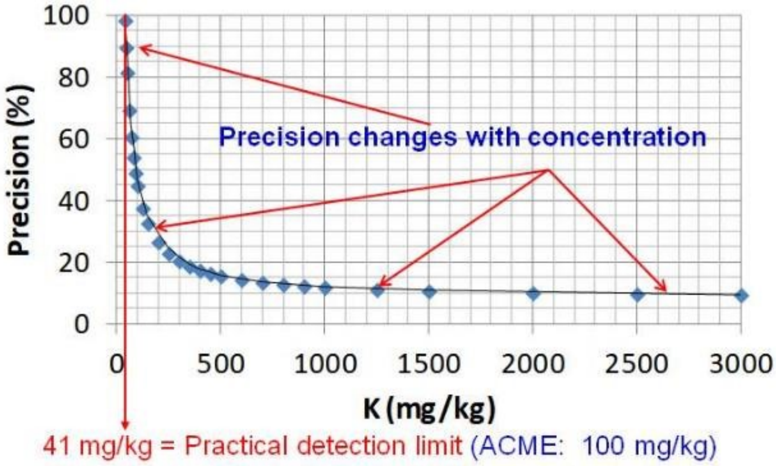


Figure A25. Sample number (sequence of analysis) plotted against the analytical results of Cr.

A11.3. Estimation of Practical Detection Limit and Precision

Figure A26 shows the potassium (K) analytical precision curve as it varies with concentration. The laboratory has given for K a detection limit of 100 mg/kg, whilst the estimated Practical detection limit is at 41 mg/kg, which is 2.5 times lower. As precision varies with concentration, the precision equation is given in order to estimate the precision at any concentration.

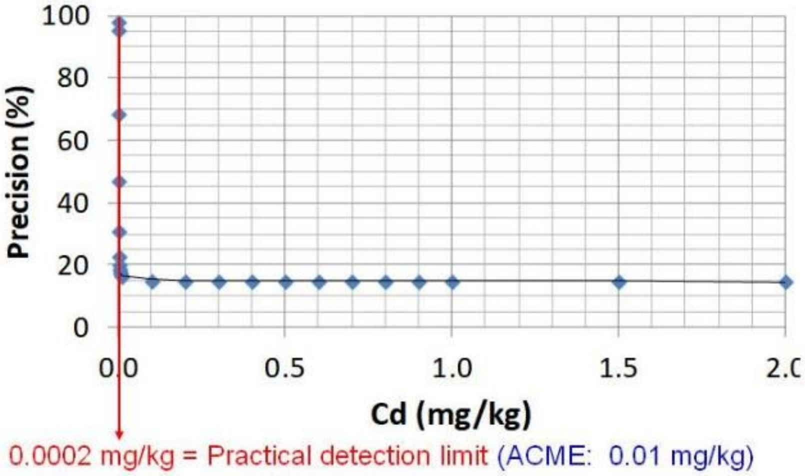


Element	Precision at the 95% conf. level		
	Pc (%) = (196.So/c) + 196.k		
	196.So	/c +	196.k
K (P_c %) =	3658.75023	/c +	7.96145

Modified Thompson and Howarth (1976, 1978) method by Demetriades (2011).

Figure A26. Analytical precision plot and estimation of practical detection limit for K, and analytical precision equation.

Figure A27 shows that the laboratory has given for cadmium (Cd) a detection limit of 0.01 mg/kg, while the estimated Practical detection limit is at 0.0002 mg/kg, which is 50 times lower.



Element	Precision at the 95% conf. level		
	Pc (%) = (196.So/c) + 196.k		
	196.So	/c +	196.k
Cd (P_c %) =	0.01612985	/c +	14.65394

Figure A27. Analytical precision plot and estimation of practical detection limit for Cd, and analytical precision equation.

Figure A28 shows a Thompson-Howarth ±10% analytical precision control chart at the 95% confidence interval. Percentile lines are plotted at 10, 20, 50, 90 and 99%. In green colour are shown the analytical results that are consistent with a precision of ±10%, and the results that are worse than ±10%.

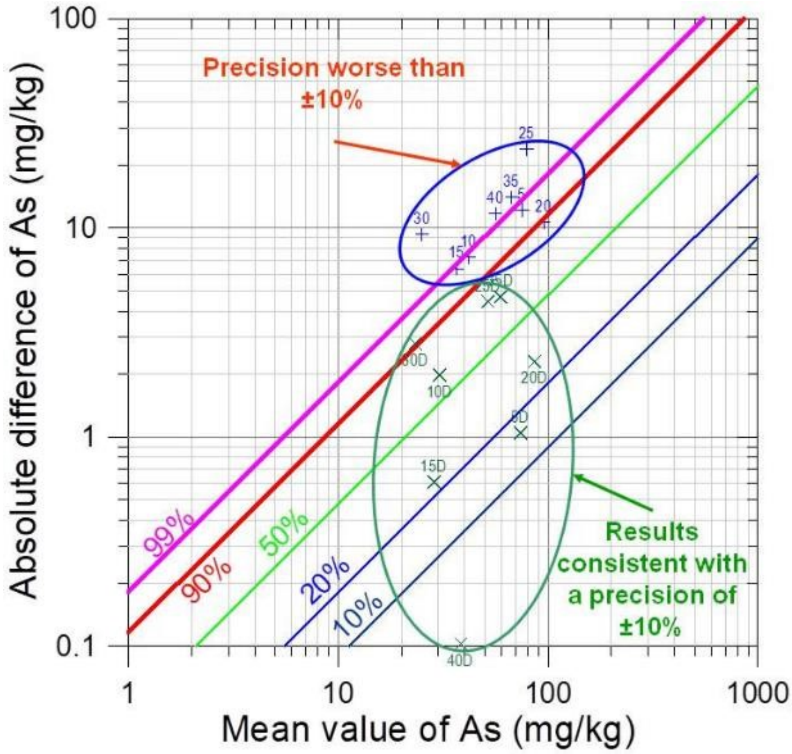


Figure A28. Thompson-Howarth plot of arsenic (As).

A balanced ANOVA design should be used for the quantification of sampling and analytical uncertainties (Figure A29).

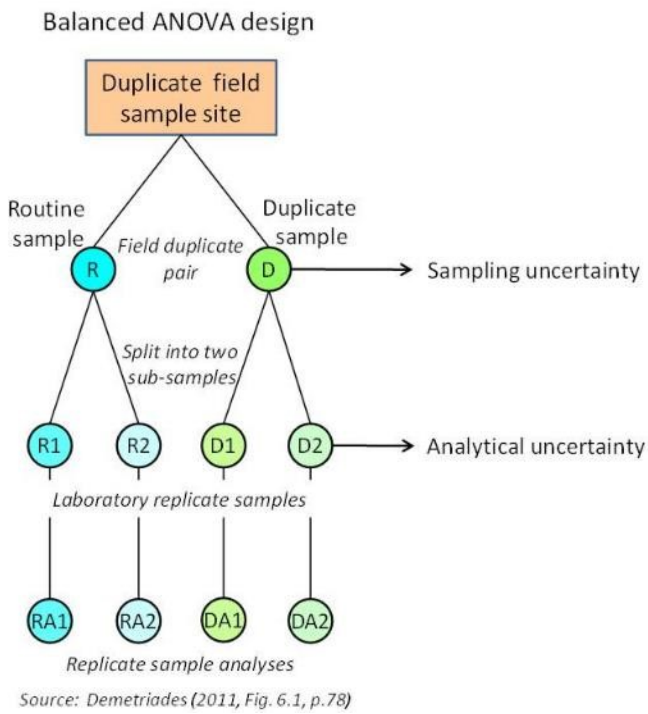


Figure A29. Balanced ANOVA design.

A11.4. Quantification of Sources of Variation

According to Ramsey et al. (1992), the maximum proportions of the Sampling and Analytical variance must not exceed 20% of the Total Variance. They even stipulate the minimum conditions to be satisfied, i.e.,

- Maximum Analytical variance should not exceed 4% of Total variance, and
- Maximum Sampling variance should not exceed 16% of Total Variance.

Therefore, the minimum Spatial or Geochemical variance should be 80% of the Total Variance, especially if the point data will be extrapolated to plot coloured surface maps.

Figure A30 displays the quantification of the sources of variation, and unacceptable and acceptable results according to fitness-for-purpose.

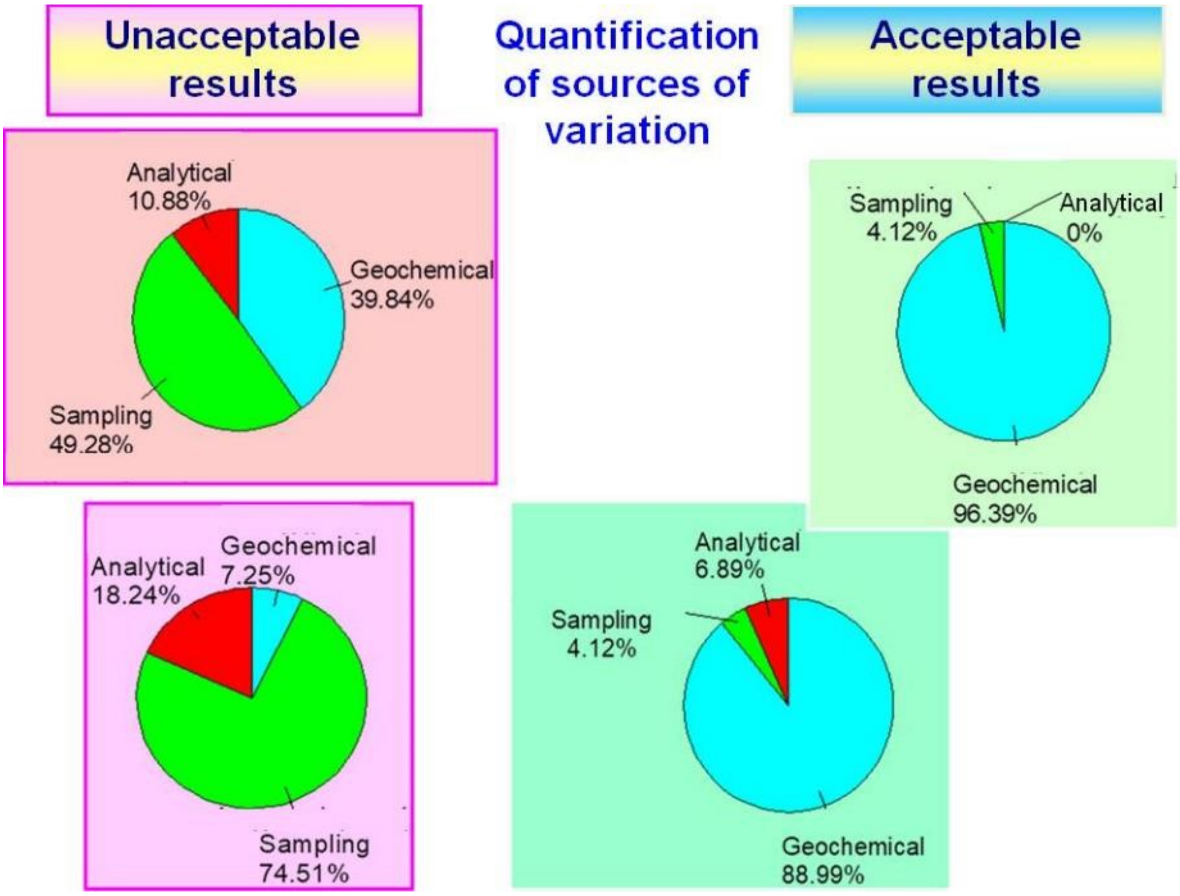


Figure A30. Pie charts showing the percentage proportion of the analytical, sampling, and geochemical variance. The pie charts on the left show unacceptable results, and the ones on the right acceptable results.

A11.5. Reporting Quality Control Results

A Quality control report MUST be written for all analytical methods used, and all problems encountered MUST be mentioned as well as the solutions given. It is strongly recommended to consult the GEMAS quality control reports (Figure A31).

Figure A31. GEMAS project quality control reports.

A11.6. Quality Control: Concluding Remarks

In case, any problems are found, these MUST be discussed with the laboratory, and if necessary, some batches of samples may have to be re-analysed for validation of the analytical results.

The quality control procedure is a time-consuming validation check, which MUST be carried out upon receiving the analytical results from the laboratory.

NEVER accept analytical results on face value, without checking their quality first. Even if the samples are analysed by an Accredited Laboratory their quality MUST be verified.

It is very important to understand that Accreditation of the laboratory does not mean that the produced results are of high quality.

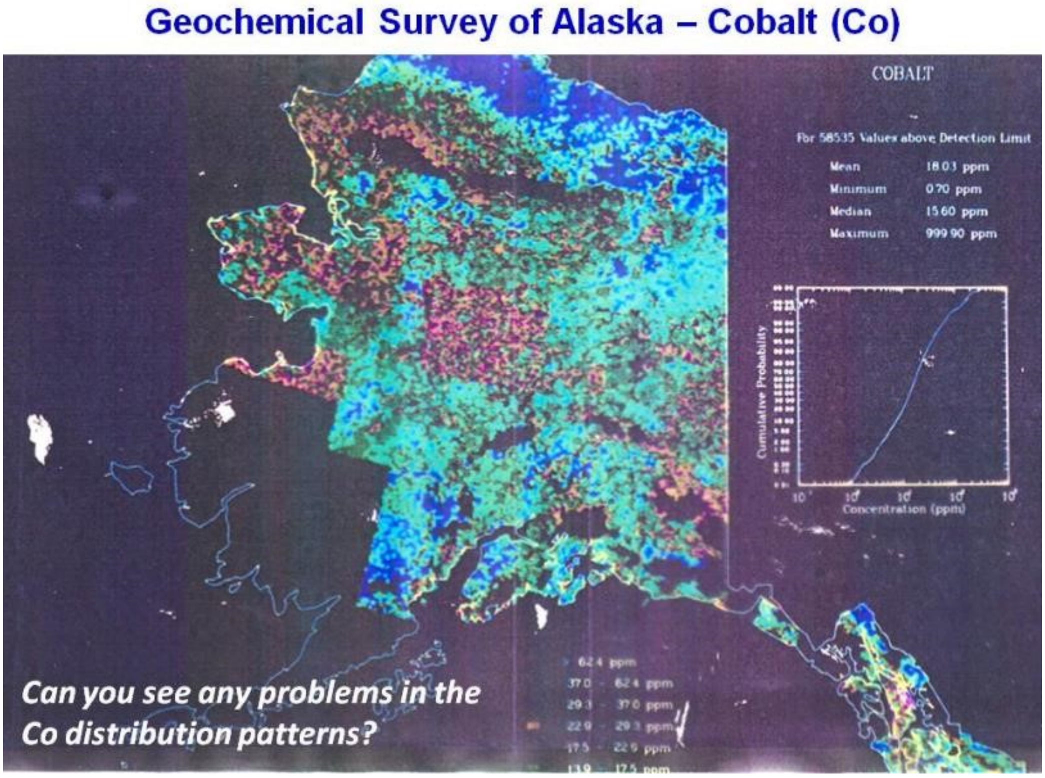
Accreditation forces the laboratory to follow a documented procedure, and nothing more.

Therefore, it is the job of a proficient and efficient Applied Geochemist to verify the quality of the project analytical results that she/he is responsible.

When the Applied Geochemist is satisfied that the results are of acceptable quality (fit-for-purpose), then and only then she/he can proceed in data processing.

Figure A32 shows the Co distribution map of Alaska, and a question is asked if any problems are observed in its distribution (a). If one is not able to see the problem of map sheet borders, the second map (b) with superimposed map sheets displays clearly the quality control problem of analysing separately the samples of each map sheet.

a)



b)

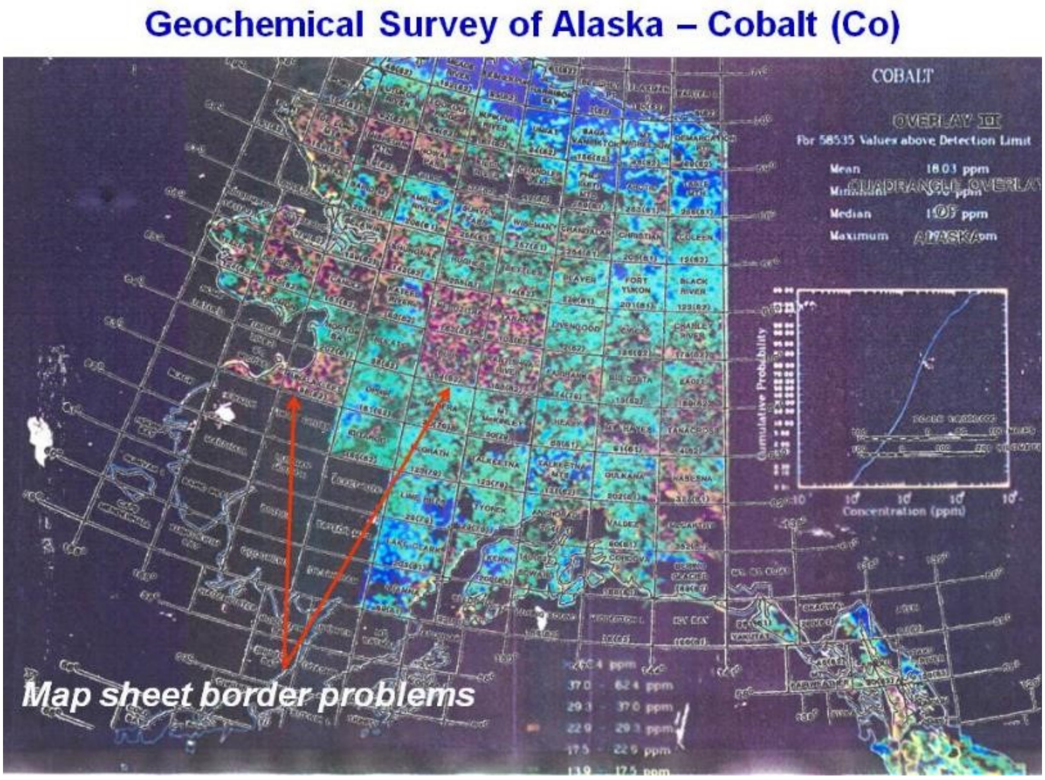


Figure A32. Cobalt distribution map, Geochemical Survey of Alaska (Weaver, 1983).

A12. SUMMARY OF POINTS AND RECOMMENDATIONS

A12.1. Geochemical Mapping Sites

- The first step is to map the Black Soil zones, because the existing map showing the global distribution of mollisols does not appear to be accurate (Figure A1).
- Second step is to plan the sampling using the 160 x 160 km Global Terrestrial Network (GTN) grid cells (Figure A15).
- During the mapping of the Black Soil zones and planning of the ≈1800 sampling sites, according to Global Terrestrial Network grid cells of 160 x 160 km, TWO large project reference samples MUST be prepared (their weight depends on the total number of samples to be collected, and enough material should remain for future use; ≈200 kg each).
- Ideally, all sampling equipment, especially the bags MUST be purchased centrally and distributed to all national sampling teams.
- Sampling manual MUST be written and tested in the field.
- All national sampling teams MUST be trained at a dedicated field training workshop, because the sampling MUST be carried out with exactly the same methodology in all participating countries.
- An appropriate and internationally acceptable soil-horizon based sampling scheme must be installed:-
  - ‘A’ soil horizon: Dig a single pit down to the C soil horizon. Remove the ‘O’ horizon if present, and sample the entire thickness of the A-horizon. A sample weight of about 3 to 4 kg should be collected (see later).
  - Alternative: Dig a single pit down to the C soil horizon, and sample the first 20 cm of the Ap horizon (ploughed layer).
  - ‘C’ soil horizon: The sample is collected from the upper level of the C horizon (just below the B horizon) to a maximum thickness of 20 cm. A sample weight of about 3 to 4 kg should be collected (see below).

    Note 1: In case the C horizon is >200 cm depth, then collect the sample from the same horizon at a depth of 180-200 cm. Again, if this particular part is <20 cm thick, then the thinner horizon is sampled, and all deviations from the sampling scheme recorded on the Field Observations Sheet.
    Note 2: The sampling teams must be well trained in order to recognise the soil horizons.
- Field photographs: Follow the order of photographing used in the GEMAS project.
- Field Observations Sheet: Record all field observations.
- Sampling density MUST be decided (the GTN density of 1 sample/5,120 km^2 is recommended).
- Duplicate field samples MUST be collected.
- Weight of each field sample MUST be decided, depending on:
  - Number and weight of sample splits to be prepared for the laboratory work that will be performed, and

- The amount to be stored as archive material for future use.

- Samples MUST be prepared in the same preparation laboratory.
- Analytical grain-size MUST be the <2 mm grain-size fraction.
- All individual samples MUST be analysed.
- Collected samples MUST not be made into artificial laboratory composite samples for analysis.
- Collected samples MUST be randomised prior to analysis, and duplicate field sample splits, international and project reference samples inserted.
- All samples for the same suite of determinands MUST be analysed at the same laboratory by the same analytical method.
- The samples MUST be analysed for total and aqua regia extractable concentrations, and by a weak leach.
- The laboratory MUST not censor element concentration values at its detection limit.
- The mineralogy of the samples MUST be determined.
- Upon receipt of the analytical results, their quality MUST be first checked and a quality control report written.
- Upon validation of the analytical results, data processing can be started.

A12.2. Monitoring Sampling Sites

- Monitoring soil sampling sites MUST be established at random sites in each participating country using the 160 x 160 km GTN grid cells.
- The agreed sampling scheme MUST be followed precisely.
- All samples MUST be prepared and analysed in the same laboratory for the same suite of determinands, following a strict quality control procedure.

Covering all Black Soil Zones with just 1800 sample sites is a task that can be easily managed.

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