Historical outline of global geochemical baselines leading to the establishment of the UNESCO International Centre on Global-Scale Geochemistry

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The Proposal for the establishment of the ***International Centre on Global-Scale Geochemistry*** **(ICGG)** in Langfang, P.R. China, under the auspices of UNESCO as a Category II Centre, was approved at the 37th session of UNESCO in Paris on the 13th of November 2013. Following its formal approval by the Chinese Government, the agreement between UNESCO and China was finally signed on the 12th of May 2016 at the formal opening ceremony of the Centre.

BjørnBølviken (1928-2009)

Arthur G. Darnley (1930-2006)

Xie Xuejing (1923-2017)

How did the idea of global- and continental-scale geochemical mapping come about? The three people with the vision to 'invent' such broad-scale international geochemical mapping were **Bjørn Bølviken** (Norway), **Arthur G. Darnle**y (Canada) and **Xie Xuejing** (China).

Let us start the story from its very beginning, because it is a tribute to the foresight of these three people. Two of them unfortunately passed away prior to the opening of the ICGG, but Xie Xuejing was alive when the ICGG opened, and was extremely pleased that his efforts bore fruit.

1980 – 1987 PERIOD

1980-1986: The first multi-national, cross-border and multi-media sampling continental-scale geochemical project was the Nordkalott (Geochemical survey of northern Fennoscandia), with the participation of the Geological Surveys of Norway, Sweden and Finland north of the 66th parallel. It started in 1980 and was completed in 1986 (Bølviken et al., 1986), with the collection and multi-element analysis of till, stream sediment, stream organic matter and stream moss samples.

1984: The concept of a World Geochemical Map was conceived at a workshop organised by the International Atomic Energy Agency (IAEA) in Sweden in 1984, but with a completely different concept (Darnley, 1990). At that time there was concern that large quantities of exploration-related geoscientific data, with many potential applications, collected on most of the continents at considerable expense, were in danger of being lost to posterity through widespread cost-cutting and cessation of operations by industries and governments. It was suggested that there should be an international effort to preserve such data. Attention quickly focused on radioelement surveys and geochemical data sets. Although more attention was placed on radioelement surveys, because of the IAEA's mandate, the advocates of the project recognised the need to make the data sets as comprehensive as possible, and to include geochemical surveys.

1986: First proposal for the continental-scale geochemical mapping of Europe, and International Geochemical Mapping. The pivotal event for continental-scale geochemistry was the Chernobyl accident in Ukraine on the 26th of April 1986. Applied geochemists then realised for the first time that no harmonised geochemical background data existed to assess the impact of such human-caused accidents that affect a whole continent. This missing and vital information was discussed on the 21st and 22nd May 1986 in Trondheim (Norway), during the inaugural meeting of the Working Group on Regional Geochemical Mapping of the then Western European Geological Surveys (WEGS; presently EuroGeoSurveys), under the chairmanship of Bjørn Bølviken, with core participants from Austria (Otmar Schermann), France (Alain Bourg), Germany (Roland Hindel), Hellas (Alecos Demetriades), Norway (Rolf Tore Ottesen, Tore Volden), Spain (Juan Locutura) and the United Kingdom (Peter J. Moore). At this meeting, the results of the then unpublished Nordkalott project were presented by Bjørn Bølviken and discussed (Bølviken et al., 1986). Similarly, the results and effectiveness of a new sampling medium, overbank sediment, were presented by Rolf Tore Ottesen and Tore Volden (Ottesen et al., 1989, 2000) and discussed. The overbank sediment results were indeed very interesting, and it was considered by the Group that this is a possible sampling medium to be used for continental-scale geochemical mapping. The meeting was concluded with the submission of a proposal to the WEGS Directors for the multi-media sampling and mapping of Europe at a density of 1 sample site/500 km^2. The proposed sampling media were: surface water, ground water, topsoil, subsoil (C-horizon), and overbank sediment (stream sediment was subsequently added). The Geological Survey of Norway was going to bear the cost of analysing all the collected samples. However, the proposal was not funded. The Group continued to push for the European geochemical mapping, and in 1988 a two-year pilot project was approved to test the sampling methodology, and especially the use of overbank (or floodplain) sediment in different morphoclimatic environments, and to compile an inventory of regional geochemical mapping projects in Europe. The Pilot Project Report (Demetriades et al., 1990), and Project Proposal (Bølviken et al., 1990) were submitted to the WEGS Directors in 1990. This resulted in the carrying out of a

further two-year research project for the collection of additional data to support such a continental-scale project. The final report and project proposal was submitted in 1993 to the Directors of the Forum of European Geological Surveys (FOREGS; Bølviken et al., 1993, 1996). The proposal was for the geochemical mapping of Europe by sampling top and bottom overbank sediment and stream sediment from catchments with an area between 60 and 600 km², and an average density of 1 sample site/500 km². The consequence of the delay in the decision-making procedure was that the offer of free analysis of all collected samples by the Geological Survey of Norway was no longer on the table.

The Chernobyl accident generated another idea, the compilation of a global radiometric map, with Arthur G. Darnley (Geological Survey of Canada) asking Bjørn Bølviken to discuss at the inaugural meeting of the WEGS Working Group on Regional Geochemical Mapping, and to consider a joint proposal for an "International Geochemical Mapping" project to be submitted to UNESCO's International Geological Correlation Programme (IGCP), presently the International Geoscience Programme.

1987: The proposal for International Geochemical Mapping was discussed during the 12th International Geochemical Exploration Symposium in Orléans (France) by a steering group comprising Arthur G. Darnley (Canada), Alf Bjørklund (Finland), Bjørn Bølviken (Norway), Pavel V. Koval (Russia), Etienne Wilhelm (France), František Mrna (Czechoslovakia) and Xie Xuejing (China), and decided to submit to UNESCO an IGCP proposal for continental-scale geochemical mapping. The proposal was supported by the International Association of Geochemistry and Cosmochemistry (IAGC; presently the International Association of GeoChemistry), and the Association of Exploration Geochemists (AEG; presently the Association of Applied Geochemists, AAG).

1988– 1996 PERIOD

1988-1992: Birth of International Geochemical Mapping. The proposal was approved as IGCP Project 259 'International Geochemical Mapping' with many countries sending information about regional geochemistry projects carried out to-date, and availability of the data (Darnley et al., 1995; Garrett et al., 2008). Chairman of the project was Arthur G. Darnley. A Special Issue of the Journal of Geochemical Exploration on 'International Geochemical Mapping – IGCP Project 259' was published in 1990 (Darnley and Garrett, 1990).

1993-1997: The project continued under IGCP as Project 360, Global Geochemical Baselines (Darnley, 1995, 1997; Darnley and Garrett, 1998; Reeder et al., 2002; Reeder, 2007; Smith et al., 2012), with Arthur G. Darley as leader. During this phase, additional work was done to establish a worldwide network of professional applied geochemists interested in implementing the recommendations of the IGCP 259/360 project for global-scale geochemical mapping projects (Plant et al., 2001). Also during this time, Xie Xuejing (Institute of Geophysical and Geochemical Exploration, IGGE, China) tested the feasibility of overbank or floodplain sediment for wide-spaced global geochemical mapping by using the whole of China as the pilot survey area (Cheng et al., 1997; Xie et al., 1996, 1997, 2011; Xie and Cheng, 1997, 2001; Xie and Wensheng, 2010; Wensheng et al., 2014; Liu et al., 2015). This was the EGMON (Environmental Geochemical Monitoring Network 1992-1995) project. During 1992-1993, top and bottom floodplain sediment samples were taken from 529 sites in eastern China. Although the sampling pattern did not follow precisely the then unpublished recommendations from IGCP 259, due to many morphoclimatic constraints, the results were very successful in demonstrating the possibility of getting a quick global geochemical overview at low cost (Xie and Cheng, 1997, 2001). Xie Xuejing led another project of the '76 Geochemical Element Atlas of Southwestern China', which is the first orientation study to determine 76 elements on composite stream sediment samples from the RGNR project to meet the analytical requirements for International Geochemical Mapping (Xie, 1995). A Special Issue of the Journal of Geochemical Exploration on 'Geochemical Mapping' was published in 1993 (Davenport, 1993).

1995: Publication by UNESCO of the final report of IGCP 259 'International Geochemical Mapping' titled: "A Global Geochemical Database for Environmental and Resource Management" by Darnley et al. (1995), which is affectionately known in the geochemical world as the "Blue Book", because of the colour of its cover. It is a fundamental publication and was well received by applied geochemists all over the world, and UNESCO, for the first time, resorted to a second printing in 1996.

Darnley et al. (1995, p.87) anticipated in their report that the progress at the international scale would be slow and they proposed the need for a permanent organisation to coordinate the work:

"*Because of the number of organisational and technical steps involved, it seems highly unlikely that any group of scientists convened under a non-government organisation, 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 recognised 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.... A World Geochemical Data Centre is required as a focal point, responsible for long term data management. This centre must be closely linked to regional centres, which could coordinate the periodic monitoring of reference sample sites in the context of global change and other environmental issues*."

The "Blue Book", after twenty years, continues to be the reference textbook for global geochemical mapping.

1997– 2007 PERIOD

1997-2006: FOREGS Geochemical Mapping Project. Directly after the publication in 1995 of the IGCP 259 report, and the recommendations of the Geochemistry Task Group (Plant et al., 1996), the Directors of the Forum of European Geological Surveys (FOREGS) approved the first multi-national and multi-sample media continental-scale geochemical mapping of Europe, according to IGCP 259 specifications. The project, under the chairmanship of Reijo Salminen (Geological Survey of Finland), started in June 1997 with the writing of a field sampling manual, which was published in 1998 (Salminen, Tarvainen et al., 1998), and ended with the publication of a two-volume Geochemical Atlas of Europe (Salminen et al., 2005; De Vos, Tarvainen et al., 2006). Twenty-seven European countries participated in the project, and collected stream sediment, stream water, topsoil, subsoil, humus and floodplain sediment samples at an average density of 1 sample site/4600 km². This is the first multinational project to make available all results through a dedicated website hosted by the Geological Survey of Finland (http://weppi.gtk.fi/publ/foregsatlas/).

1997: Establishment of the Working Group on Global Geochemical Baselines. The International Union of Geological Sciences (IUGS), in collaboration with the International Association of Geochemistry (IAGC), established the Working Group on Global Geochemical Baselines (Reeder et al., 2002; Reeder, 2007; Smith et al., 2012) (later the name was changed to the Task Group on Global Geochemical Baselines) under the leadership of David B. Smith (USA) and Jane Plant (UK). The Task Group's main objective was to encourage and facilitate the establishment of a global geochemical database through application of the sampling, sample preparation, analytical and data management protocols recommended in the 'Blue Book' (http://www.globalgeochemicalbaselines.eu/).

2002-2003: After contacting different international bodies to take the lead of the Global Geochemical Baselines project and receiving negative replies, Alecos Demetriades (Hellas) got in touch with Xie Xuejing (China) and proposed that China should consider taking the

lead in Global Geochemical Mapping, as it has the facilities to carry out such a project. Xie Xuejing pursued this idea and with his wise thinking and vast experience, planned very carefully, patiently and systematically, step by step, how he would convince the necessary people from different walks of life about the importance of this project, not only for China, but for the whole World, and gain their support.

2003-2015: The North American Soil Geochemical Landscapes Project was initiated in 2003 with the United States of America (USA), Mexico, and Canada collaborating with the intent to collect soil samples at a density of 1 site per 1600 km² throughout these three countries. Canada dropped out of the project in 2009, but the USA and Mexico completed sampling and chemical analysis. The results from the USA are published in Smith et al. (2013, 2014), and are freely available from a dedicated website hosted by the United States Geological Survey: https://pubs.usgs.gov/of/2014/1082/. At present, Mexico has not made its data available to the public. Although these projects, as well as the Australian project discussed below, do not follow "Blue Book" specifications to the letter, they were important to generating interest in establishing the Centre by showing that continental-scale surveys were being conducted outside of Europe and China.

2005-2008: International Geochemical Mapping Project launched by China and led by Xueqiu Wang, with co-partners Colombia, Kazakstan, Mongolia, Egypt (dropped out), South Africa and Europe (determination of additional elements on FOREGS atlas samples in China). This project was of crucial importance for international cooperation on global geochemical mapping, which led over 30 countries from Asia, Africa, Latin America and Europe to participate in the project since 2005.

2007-2011: The National Geochemical Survey of Australia (NGSA) was initiated in 2007 as a collaboration between Federal and State geological surveys to deliver Australia's first continental-scale geochemical data set and atlas. The chosen sampling medium was catchment outlet sediment, similar to floodplain sediment, which was collected from two depths near the outlet of 1186 large catchments, covering over 6 million km² at an average density of 1 site/5200 km2. The data and several reports are freely available from http://www.ga.gov.au/ngsa and the atlas was published in Caritat and Cooper (2011).

2008– 2016 PERIOD

2008-2014: The China Geochemical Baselines (CGB) project was launched in 2008 and led by Xueqiu Wang, as part of global geochemical baselines covering this time the whole of China. The project was completed in 2012, with the collection of 6617 top and bottom samples in 3382 catchments in 1500 CGB grid cells across 9.6 million km2 at an average density of 1 sample site/3000 km2 (Wang and The CGB Sampling Team, 2015). The catchment basin samples, included floodplain, overbank and seasonal lake sediment samples, which were taken in China's diverse landscape of plains, mountains, desert, grassland, loess and karst in order to obtain a nationwide high-resolution and harmonised baseline data. Seventy-six chemical elements plus 5 additional parameters were determined. It is the only project that meets the requirements for the analysis of 71 elements recommended by the Global Geochemical Baselines Project. The database and maps are managed by an Internet-based software named Digital Geochemical Earth (http://www.globalgeochemistry.com).

2008: In September 2008, Xie Xuejing proposed the establishment of an International Centre on Global Geochemical Mapping in IGGE (Langfang, Hebei Province, P.R. China) to Dong Shuwen, the Secretary of the China National Committee of IGCP. During the business meeting of the IUGS/IAGC Task Group on Global Geochemical Baselines at the 33rd International Geological Congress in Oslo, Xueqiu Wang (China) accepted the position of co-leader of the Task Group, replacing Jane Plant who had stepped down.

Publication of a Special Issue of Geochemistry: Exploration, Environment, Analysis titled 'Thematic set in honour of Arthur G. Darnley (1930-2006)' (Reimann and Smith, 2008).

2009: In July 2009, during the visit of Walter Ed Aaron, Assistant Director-General of UNESCO to China, Liu Duiyi, on behalf of the China National Committee of IGCP, proposed the setting up of an International Centre on Global Geochemical Mapping in China, and received his positive response.

In October 2009, the Global Geochemical Mapping Symposium was held in Langfang, and the proposal for the international centre was discussed. All participants expressed their support for the establishment of an International Research Centre for Global Geochemical Mapping in the Institute of Geophysical and Geochemical Exploration (IGGE), Langfang, P.R. China. As an outcome of this meeting, Xie Xuejing (China), David B. Smith (USA) and Xueqiu Wang (China), forwarded a proposal to the China IGCP National Committee for establishing an International Research Centre on Global Geochemical Mapping (the name was changed later to International Centre on Global-Scale Geochemistry) under the auspices of UNESCO. The proposal was also supported by the Ministry of Land and Resources of P.R. 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 on Global Geochemical Baselines, the China Geological Survey (CGS), the Chinese Academy of Geological Sciences (CAGS), and the Geological Society of China.

2010: In February 2010, Xueqiu Wang and Wensheng Yao attended the 38th Session of the IGCP Scientific Board in Paris. Xueqiu Wang, as representative of the IGCP China National Committee, IGGE and CAGS, delivered a report proposing the establishment of the International Research Centre on Global Geochemical Mapping, including its background, objectives and significance, functions and tasks, eligible qualifications, administrative mechanism and organisational structure, budget and its sources. The proposal was well received (Resolution IGCP.R.38.1) and Alberto Riccardi (IUGS President) and Robert Missoten (IGCP Secretary) expressed their full support.

In October 2010, the Ministry of Land and Resources submitted a formal request to the UNESCO Director-General, through the Permanent Delegation of the People's Republic of China, to carry out a feasibility study for the establishment of a Category 2 Centre in Langfang, co-located with IGGE (State Research Institute). The UNESCO Director-General sent in November 2010 Robert Missotten (IGCP Secretary) to China to conduct a feasibility study, which among other matters proposed that the centre should be named the 'International Centre on Global-Scale Geochemistry'.

2011: The IGCP Scientific Board reviewed the feasibility study report and drafted a resolution (187 EX/14 Part VII) in support of the proposal at the 39th IGCP Scientific Board Meeting, 16th to 18th February 2011.

2013: The decision was adopted by the UNESCO Executive Board at its 191st session in Paris on the 3rd of June, 2013 (191 EX/14 Part III). Finally, the proposal was approved by the General Conference at its 37th session in Paris on the 13th November 2013 (35 C/ Resolution 103).

In December, 2013, the IGGE established an ICGG working group, supervised by Xie Xuejing, led by Han Ziye (former IGGE Director), and Xueqiu Wang was appointed as the ICGG Executive Director for the Centre's management.

2014: A Memorandum of Understanding (MoU) on Global Geochemical Mapping of five year duration was signed on the 22nd of October 2014 by the IUGS and the CGS in Tianjin (China). The IUGS has always strongly supported global geochemical mapping

through the IGCP 259 and IGCP 360 projects, and the IUGS/IAGC Task Group on Global Geochemical Baselines (presently the IUGS Commission on Global Geochemical Baselines). 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 Research 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 aimed at:

Launching Global Geochemical Baselines Mapping Project - Chemical Earth, promoting the establishment of a global network for the project and developing 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 mapping, 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 (IGC), 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.

2015: In September 2015, the establishment of the Centre was approved by the State Council P.R. China Government after the recommendation by the Ministry of Land and Resources, the Ministry of Foreign Affairs, the Ministry of Finance, the Ministry of Education and the Ministry of Science and Technology. Subsequently the Ministry of Foreign Affairs P.R. China authorised the signing of the UNESCO-China agreement.

A budget of 2 million Yuan (approx. 0.3 million US$) per year for running costs was approved by the Ministry of Finance. A six-year term (2015-2020) financial support plan for the Global Geochemical Mapping Project was approved by the China Geological Survey via the Ministry of Land and Resources, and a budget of approximately 20 million Yuan (approx. 3 million US$) per year for the project was sponsored by the Ministry of Finance.

2016: Establishment of the UNESCO International Centre on Global-Scale Geochemistry. On the 12th of May 2016, during a festive opening ceremony in a newly constructed building within the premises of IGGE in Langfang, P.R. China, the Agreement between UNESCO and China for the establishment of the International Centre on Global-Scale Geochemistry was signed.

Another important step was the decision of IUGS on the 31st of August 2016 at its Fourth Ordinary Session in Cape Town to establish an IUGS Commission on Global Geochemical Baselines.

With the establishment of the International Centre, the 'Blue Book's' vision of a single organisation to coordinate global geochemical mapping efforts throughout the world is now a reality.

APPENDIX: DEFINITIONS

Global-scale geochemical mapping: the systematic collection and chemical analysis of a large number of samples (soil, sediment, rock, surface water, ground water, etc.) evenly distributed throughout the land surface of the Earth accompanied by the display of the resulting data on a topographical, geological, lithological or other map types. This type of mapping is normally done at a very low sampling density (1 to 10 sites per 10,000 km^2) for cost efficiency reasons.

Global-scale geochemistry: the study of the composition and spatial distribution of chemical elements and compounds in the various environmental compartments (soil, sediment, rock, surface water, ground water, etc.) of the Earth and the determination of the processes that cause the observed distributions.

Global geochemical baseline database: a digital repository of harmonised and quality controlled global-scale geochemical data systematically organised to allow for easy access, management, and updating.

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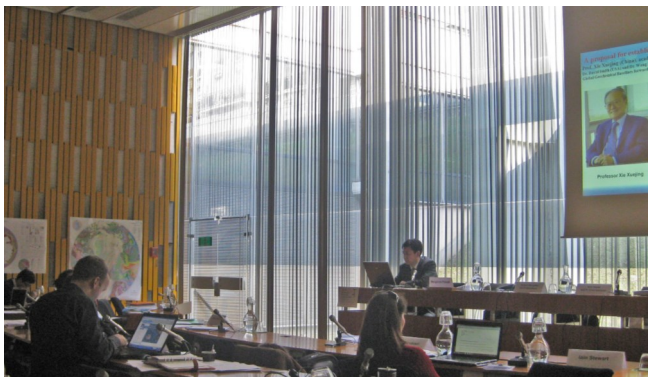
Geochemists discussing the establishment of the Centre during Global Geochemical Mapping Symposium held in Langfang, October, 2009.



Dr. Wang Xueqiu Delivering the proposal report for the Centre establishment in the IGCP meeting, February, 2010.

Group photo of IGCP Board members and the representatives of the Centre, Paris, February, 2010.

Representative of UNESCO Director-General, Dr. Robert Missotten, conducting the feasibility study in Langfang, November, 2010.