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RAPPORT

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Geochemistry in Geological Surveys into the 21st Century

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Geochemistry has a important role to play in Geological Survey activities in the 21st Century. However, as distinct from the 20th Century, environmental issues may eventually become more important than resource issues in sustainable development decision making; in fact this has already happened in some countries. Surveys in countries with active mineral industries that provide employment opportunities for their communities will need to maintain geochemistry expertise concerning mineral exploration, especially the search for deeply buried resources. However, all Surveys will be required to provide, and should take on responsibility for providing, natural process expertise so that ecosystem and human health risk assessment and management decisions are properly informed, and that policy and regulation are founded on sound science.

With globalization a feature of the late 20th Century and current times, there will be increasing demands for data and information at global scales to ensure various aspects of 'level playing fields'. Geological Surveys need to ensure that guidelines, protocols and standards are collaboratively developed so that expensively acquired data are compatible and can be integrated into global-scale studies. More than 80 % of the world's population now lives in urban centres. Urban geochemistry, and thus data collection on a very local scale, is becoming increasingly important and relevant to societal decision making.

Data that support understanding of the processes controlling transport of substances (trace elements and compounds) between lithosphere, pedosphere, hydrosphere, biosphere and atmosphere, and their fate that ultimately link to human health, are urgently needed. Continental scale coverage is required and should be undertaken stepwise in large increments as multi-media, multi-element surveys. Close collaboration with soil scientists, biologists, toxicologists, epidemiologists, and medical researchers will be needed to delineate the pathways of natural and anthropogenic contaminants, and identify cause and effect relationships between their occurrence and ecosystem and human health.

Both continental (or global) and urban (local) scale are ultimately linked via 'human health issues'. Medical Geology may provide an important vehicle to better sell the importance of regional geochemistry to politicians, regulators, decision makers and the general public.

Emneord: Geochemistry	New challenges	Regional geochemistry
Urban geochemistry	Multi-element	Multi-medium
Laboratory	Geological Surveys	

INNHOLD

Geochemistry in Geological Surveys into the 21st Century

Preface

A group of experienced geochemists with different backgrounds (from Government Geological Surveys in Canada, Finland, Norway, Sweden, the United Kingdom and the United States of America, and from Universities in Finland and the United Kingdom) met in Helsinki to discuss the status and future trends in applied (terrestrial) geochemistry in government Surveys. This document is the consensus reached during the 1.5 days of discussions on what geochemistry in government surveys should focus on in the new Century, and how best to serve those who require geochemical knowledge and data to fulfil their roles in society.

The facts exposed and the views expressed are interesting and relevant to the discussions on the future of applied geochemistry in any Survey organisation. It is for this reason that NGU decided to make the document publicly available in the form of a NGU open file report.

Arne Bjørlykke
Director General
Geological Survey of Norway (NGU)

Geochemistry in Geological Surveys into the 21st Century

a Workshop held at the Geological Survey of Finland
Espoo, Finland, June 12th and 13th, 2003

Background

The workshop took advantage of the opportunity for geochemists who were travelling from the 5th International Conference on the Analysis of Geological and Environmental Materials (June 9-11), Geoanalysis 2003, in Rovaniemi, Finland, and/or on their way the 7th International Conference on the Biogeochemistry of Trace Element (June 15-19) in Uppsala, Sweden. The meeting was jointly organized by the Geological Surveys of Finland and Norway (GTK and NGU - Dr. Reijo Salminen and Dr. Clemens Reimann) to provide a venue where geochemists working at national Geological Surveys could compare notes concerning the role of applied geochemistry in their agencies in the new century.

Those present were:

Alf **Bjorklund** (ex-GTK now University of Turku and industry, Finland)
Bob **Garrett** (GSC, Canada)
Gwendy **Hall** (GSC, Canada)
Kaj **Lax** (SGU, Sweden)
Kirk **Nordstrom** (USGS, U.S.A)
Rolf Tore **Ottesen** (NGU, Norway)
Vala **Ragnarsdottir** (Univ. of Bristol, U.K.)
Shaun **Reeder** (BGS, U.K.)
Clemens **Reimann** (NGU, Norway)
Reijo **Salminen** (GTK, Finland)
Timo **Tarvainen** (GTK, Finland)

A list of issues to be discussed had been circulated prior to the meeting. Clemens Reimann, as co-organizer with Reijo Salminen, opened the meeting. Following a ‘round table’ where attendees introduced themselves, there were a number of short presentations focussing on the activities of the different Geological Surveys, and participants introduced issues of specific concern to them and their organizations. In the light of the introductory discussions a list of issues was developed for consideration based on previously circulated list. This report commences with a Summary and Recommendations section, and the record of detailed discussion is presented in the framework of the identified issues. Vision and Mission statements referred to by participants may be found in Appendix 1.

In the following text the word survey is used in two senses. Therefore, *Survey* will indicate a Geological Survey organization, and *survey* will indicate a geochemical survey activity.

It should be noted that marine geochemistry was not represented at the meeting and the report does not, therefore, refer to marine issues. This should not be taken as an indication of any lack of relevance to geochemistry in Geological Surveys, but reflects the participants' lack of expertise in the field.

Summary and Recommendations

Two major political developments were recognized as important influences on the tasks of geochemists in government Geological Surveys at the beginning of the 21st century:

1. Globalization - With globalization becoming a feature of the late 20th Century and current times, there will be increasing demands for data and information at continental and global scales; and
2. Urbanisation - More and more people live in urban areas. Already about 80 % of the global population lives on only 2 % of the land area - detailed data on the urban environment are thus needed.

At many Geological Surveys regional geochemistry has been until quite recently focussed on national scale studies, often related to resource issues, and using different sample materials, sample densities and analytical procedures. Demand by governments and the public has shifted towards data with environmental relevance, often requiring different sample materials (i.e. soils instead of stream sediments) and a different analytical focus. In addition data are needed that are comparable across national borders. Geological Surveys have an important role to play in establishing joint protocols for such undertakings.

Multi-element geochemistry has had its stronghold in Geological Survey organizations for more than 40 years. Geological Survey laboratories were at the leading edge of developing analytical techniques for inorganic analysis and improving detection limits. This strength should not be given up, nor should the world class expertise that has led to the successful transfer of innovative protocols and methodologies to other government agencies, industry and universities. However, the funding of these laboratories, including the capital required to purchase increasingly sophisticated analytical instrumentation, is in jeopardy. While 'routine' analyses can, with the implementation of thorough QA measures, be contracted out to commercial laboratories, Surveys must retain their expertise in each of the major analytical techniques and continue to transfer newly developed methods to the private sector. Neither Industry nor Academia has the required resources, dedicated expertise or mandate to fulfill this role of scientific leadership.

Today geochemical data are needed at different scales: continental, national and local for a wide variety of different purposes. Geological Surveys have a unique opportunity to become national data base centres for environmental data. There are no other organizations yet working at (and realizing the importance of) all these scales. However, as political demand for such data increases, other organizations will begin to position themselves in this field if Surveys do not take advantage of the present situation. In Europe (EU Soil Monitoring Directive) there is a strong possibility that a European Soil Survey will be established, one role of which could be the provision of soil chemical data.

Data that support the understanding of the processes controlling transport of substances (trace elements and compounds) between lithosphere, pedosphere, hydrosphere, biosphere and atmosphere, and their fate that ultimately link to human health, are urgently needed. Continental scale coverage is required and must be done stepwise in large increments as multi-media, multi-element surveys. Close collaboration with soil scientists, biologists, toxicologists, epidemiologists, and medical researchers will be needed to delineate the pathways of natural and anthropogenic contaminants, and identify cause and effect relationships between their occurrence and ecosystem and human health.

Both continental (or global) and urban (local) scale are ultimately linked via 'human health issues'. Medical Geology may provide an important vehicle to better sell the importance of regional geochemistry to politicians and the general public.

Record of Detailed Discussion:

1. Who needs our data?

The trite answer was, 'everyone', but in that response there is a grain of truth as geochemical data are widely used in environmental and health studies as well as in traditional geoscience studies. In those Surveys with surface and groundwater responsibilities enquiries concerning chemical water quality are frequent, and concern elements such as As, Hg, Cr and POPs. It was noted that questions re Pb appeared to be less frequent. A common question to all Surveys would appear to be "What are the [metal] levels in the [location] area?". This question is being posed by both the public, who have been sensitized to environmental issues, and sister government departments at national, regional and local levels whose responsibilities include environmental monitoring and management. It was clear that traditional questions concerning mineral resource and exploration uses of geochemical data were relatively rare in Europe and North America, except in Finland, Sweden and Canada. It was noted that with greater interest by government and societies in environmental issues Other Government Departments (OGDs) and Agencies (OGAs) are becoming important clients at the expense of industry.

Some participants noted that academics and their students acquired Survey generated geochemical data to support their research projects and for investigation in thesis studies. However, it was mourned that the excessive cost charged by some European Surveys makes it impossible to use these data for research and teaching purposes.

With reference to the FOREGS (Forum of European Geological Surveys) Geochemical Baseline Programme (FGBP), this project was initiated to provide high quality environmental geochemical baseline data for Europe. The data are based on samples of stream water, stream sediment, floodplain sediment, soil and humus collected from all over Europe. It was reported that a decision had been made by FOREGS Directors that, to speed release of regional geochemical maps and avoid copyright issues associated with commercial publication, one of the participating Surveys (to be decided) would publish the maps and summaries of the FGBP on the Internet so that they would be freely and instantly available. This decision was made as this kind of information is becoming of increasing importance to society, and is being requested in EU legislation and for other related purposes, e.g., exposure and risk assessments. It was also agreed that after a one to two year delay to permit participating FOREGS Survey staff to publish scientific papers based upon their work the full database would become freely available.

The consensus was that geochemical data are needed at different scales, continental, national and local, for a wide variety of different purposes. Geological Surveys still have the unique opportunity to become national data base centers for environmental data because no other organization is yet working at all these scales. However, as political demand for such data increases, other organizations will begin to position themselves in this field if Surveys do not take advantage of the present situation.

To be of use in contributing to environmental issues a number of elements that are not routinely determined as part of ‘classical’ geological studies need reliable analysis at very low levels at or below currently widely available detection limits, e.g., Ag, Be, As, Hg, Th, Tl, U and many others. Multi-element analytical geochemistry (40 or more elements per data set) is one of the major competitive advantages of geochemistry at Geological Surveys. It was also discussed to what extent organic geochemistry (e.g., analysis for PAHs and PCBs, pesticides, etc.) belongs on the agenda of Geological Surveys.

Furthermore, the comment was made that Geological Surveys need to hire people with ‘sales’ expertise and capabilities who can present geoscience, including geochemical, data and help build client/user communities. The USGS has 6 staff members whose responsibility is liaison between the agency and Congress, and a similar number who provide liaison with other parts of the Department of the Interior and other federal agencies; today, staff like these are essential to ensure continued support of USGS programs. In Canada it is planned to use the National Atlas web site to provide greater exposure to regional geochemistry; the site will include explanatory text at the High School level.

2. What kind of geochemical data are really needed by society?

A diversity of opinions was expressed, reflecting the activities being undertaken in different Surveys, concerning sample media and their particular analyses. For instance, where groundwater studies are a Survey responsibility the need for bedrock geochemical data appeared to be more important due to its use in groundwater-bedrock interaction studies.
It was pointed out that in a human health/societal context 80% of the world’s population lives in cities that occupy some 2% of the global land surface. Furthermore, in developing countries urban agriculture, often on polluted soils

irrigated with polluted waters, accounts for some 70% of food production. In countries where the Geological Surveys have claimed ‘urban geochemistry’ as their mandate, the acquisition of data to support environmentally related decision making is a major need expressed by regional and local government agencies. Furthermore the two Surveys present who reported growth in their geochemical activities were Norway and Sweden, and in both cases the growth was to support urban geochemistry studies. The British Survey is expanding its urban geochemistry activities, it has already been active for several years; the Finnish Survey is undertaking detailed studies around, but not in, urban areas; and the U.S. and British Geological Surveys are both active in ‘brownfields’ studies.

From environmental perspectives, the consensus was that the media of maximum interest were: ground and surface water, and both urban and agricultural (inc. forestry) surface soils. This was summed up as, “the geochemistry of what we live on and off”. From traditional geoscience and mineral exploration perspectives, the consensus was that freshwater stream and lake sediments and waters, glacial sediments (and their weathering products) and rocks (a distant third) were the prime media of geochemical survey importance. In connection with rocks, a reason for the lack of concern over such data is the cost of acquiring representative sample sets and data for them in comparison with surface sediments (freshwater and glacial) and their derived products. Surface sediments, and in the case of glacial sediments the soils developed on them, reflect homogenization processes that make individual point data more representative of source/bedrock materials upstream or up-ice. Having said this, all agreed that in studying the biogeochemical cycle and understanding the sources, cycling, transport and fate of chemical substances it was necessary to study the geochemistry of the wide range of media present in a study area. There was a consensus that it was important for geochemists in Surveys to collaborate with soil survey scientists, often located in Departments of Agriculture, on trace element and micronutrient studies because of the contributions Survey geochemists can make from their knowledge of the biogeochemical cycle.

An increasingly important question is that of natural vs. anthropogenic sources of hazardous elements and compounds in soils, sediments, and water bodies. Surveys are in a unique position to investigate and discriminate between naturally occurring or ‘background’ concentrations and anthropogenic concentrations of harmful substances so that a fair and unbiased assessment can be made for remediation and liability.

In the context of analytical requirements, it was noted that in recent years As and Se were being routinely determined. For mineral exploration there were increasing requests for better (lower detection limit) Ag, Bi, Sb and Te data; while for environmental studies Tl data were in increasing demand. In addition, participants stressed the importance and value of a range of dissolution procedures that measure the fraction of an element in a sample that is relevant to a particular problem, e.g., the metal transported in the liquid or vapour phase away from a mineral deposit, or the bioavailable fraction of an element that can impact ecosystem or human health or food quality. The matter of Persistent Organic Pollutants (POPs), e.g., DDT, Lindane, Dioxins, PCBs, PAHs, etc., was briefly discussed because of their importance in environmental studies. In Norway selected POPs are routinely determined by the Survey in urban study samples; in the U.K. similar analyses are undertaken by contracting service laboratories; in Sweden only marine sediments are analysed for PCBs; and in the U.S. selective POPs are determined in hydrologic systems depending on need and funding. The consensus was that Surveys should the focus on two scales (their mandates permitting):

- Urban geochemistry; and
- Large (preferably continental scale) multi-media, multi-element studies.

However, it was recognized that work at other scales makes important contributions to Survey programs.

For urban studies determinations of some organic compounds (totals, not separate congeners) will be required to meet survey and risk assessment requirements (e.g., PAHs and PCBs). Urban geochemistry also needs high density sampling to be useful to risk assessors and managers (i.e. hundreds of samples per city).

For continental scale studies the focus should probably be on inorganic geochemistry, any organic chemistry requirements should be met through collaboration in sample design and analytical protocol development with other concerned agencies. A comparison of a number of different media, collected and analysed by equivalent methods would deliver the most useful results in terms of large-scale geochemical processes. A low sample density (1 site per 2500 to 5000 km^2) is sufficient for these studies. Agricultural soils would appear to be one of the most important sample materials. Water data are also in great demand. Again the most contribution that Geological Survey organizations could make would be in creating continental scale directly COMPARABLE databases.

3. Regional geochemistry, are we finished?

Clearly the answer is both “Yes” and “No”. In many European countries (especially Finland) adequate regional geochemical surveys based on regionally appropriate sample material have been completed. In some, e.g., Sweden and the U.K., work continues, but in the U.K. completion is in sight. In others, e.g., Canada, traditionally scaled regional geochemical surveys continue to meet specific socioeconomic (both economic development and environmental baseline) requirements. A major issue with the existing data sets is that they are often incompatible across national borders, and, as a result, large trans-national continental scale geochemical processes are often not recognized.

The need for further geochemical surveys was discussed, and focussed on two very different scales and objectives. Firstly, regional and local (county) governments have expressed a need for more detailed geochemical data on which to base land-use and risk management decisions. Secondly, at the other extreme, Geological Surveys and Environmental Agencies have expressed the need for very broad spatial continental, trans-national or super-regional data for several purposes: 1) to establish baselines for use in environmental issues; and 2) to provide a consistent trans-national framework into which more detailed surveys can be placed, compared and integrated. Examples of the latter surveys are the published Kola Ecogeochemistry and Baltic Soil surveys; the completed FOREGS trans-European and Barent's surveys presently being written up for publication; and the U.S.-Canadian-Mexican North American survey currently under discussion. In the context of these trans-national surveys there was some discussion of the required sample size. Some participants expressed the opinion that sample sizes of 1000 (a Bol, named after Bjorn Bolviken of the Norwegian Geological Survey) appeared to work well due to the apparent fractal nature of geochemical data. That is, at whatever scale one looks at geochemistry, a mineral grain, a country, or a continent, there appear to be mappable patterns than can be related to geochemical and geological processes. An outstanding research issue is, just what is an optimal sample size? Knowledge of this will increase the effectiveness and efficiency of future geochemical mapping activities.

In the context of the above discussion it was noted that geoscientists are, along with astrophysicists, one of the few groups with an ability to think and work at widely different temporal and spatial scales. This should be considered an important asset, and has the potential to make geoscientists unique contributors to multidisciplinary studies where such thinking and understanding contributes to project success.

It was agreed that although the field and analytical components of many regional geochemical surveys on the national scale had been completed, there was in many cases a need to interpret the data and publish it in forms that would both inform the non-geoscience user and provide the information required by other geoscientists to support their work. Interpretation is often a greater challenge than producing a map because the complexity of environmental processes can suggest multiple sources or processes, leading to multiple hypotheses, and requiring expertise that can discern between the influences of competing complex processes.

Finally, it was recognized that the major challenges lie at the broad scale where best available methods need to be developed for multi-media multi-element surveys that will serve those interested in and requiring geochemical data to support a wide range of geoscience and environmental issues.

4. Are there competitors?

The matter of 'competitors' to Geological Survey regional geochemistry was discussed, and two were identified. Firstly, in the context of environmental monitoring, moss surveys such as those routinely undertaken at 5-year intervals in Europe. The data show significant decreases in 'metal' levels in moss in recent years, however, the data themselves raise questions as to quality and QA/QC as significant shifts in level occur at national boundaries (e.g., the 1998 survey). Moss surveys have not been regularly employed by

Surveys except in major multi-media surveys, e.g., Kola and Barents where anthropogenic impacts and their differentiation from geogenic background has been an important issue. Secondly, soil surveys, most commonly undertaken by Departments of Agriculture or national Soil Surveys. In Europe potential 'turf battles' have been avoided in some countries by Geological Surveys generating data for the <150 Φm fraction of soil, leaving the traditional <2 mm fraction to the Soil Surveys. Unfortunately this limits the utility of Geological Survey data as the <2 mm fraction is the international standard for agricultural and environmental studies. This situation has not arisen in North America where collaboration, rather than competition, has been the norm.

The consensus was that collaboration was the best path forward with both soil scientists and geochemists contributing their knowledge and experience to common goals. Socially relevant possibilities may lie in collaboration with biologists and toxicologists.

5. Why are there Geological Surveys? Strengths and Weaknesses

It was noted that while Geological Surveys were founded in the last one-and-a-half centuries to identify and assess the natural resources of nations, and to support mineral industries, there has been a shift over the last quarter century, almost total in some cases, to the study of environmental issues. Currently the Portuguese geological survey organization is under threat of extinction, and it is common in Europe that Geological Surveys report within Departments of the Environment, rather than Natural Resources of Industry.

Thus, with governments and populations more concerned with environmental and human health issues than natural resources and mineral/metal supply it was only to be expected that the focus of Geological Surveys has changed away from traditional geoscience and mineral resource studies. It was agreed that geochemists were better suited to this change than some other geoscience specialities as their knowledge and expertise concerning the sources, transformation, transport and fates of 'metals' had equal relevance to both resource and environmental applications.

All agreed that an important strength of national Surveys was their reputation and record of impartiality. The term "Honest Broker" was used by several participants, and exemplifies the position taken by Survey officers in bringing sound science concerning natural processes to the development of regulations and the assessment and management of various risks to society. This is enhanced by the fact that most Surveys do not have regulatory or enforcement responsibilities. However, this latter point may also be seen as a disadvantage, as in the absence of regulatory or other fiduciary responsibilities the question may be asked, "do we really need a Geological Survey?"

The comment was made that, amongst physical scientists, geologists and Geological Surveys were one of the few groups that willingly took on continental scale activities. As such, there was potential for Surveys to add a unique perspective to multi-disciplinary studies in collaboration with other agencies. It was noted that Geological Surveys are the only agencies that can provide unbiased, objective, scientific evaluation of environmental contaminant issues that may involve geology, geochemistry, hydrology, etc. As tax-supported agencies without enforcement responsibilities and without direct ties to industry, we can make objective studies of environmental systems and clarify sources and pathways of contaminants that are needed by regulatory agencies to make wise management decisions. An example of this is the 1997-2002 Metals in the Environment Initiative at the Geological Survey of Canada where major studies were made of metal footprints around several base metal smelters in Canada.

Geological Surveys have long-term commitments to geoscience and act as repositories for national collections, both physical sample material and archival storage of map, reports and data. As such they form a part of the national science infrastructure, providing access to this material and the expertise to interpret it and use it to focus on problems of national concern as they arise. It is through archival data, long-term monitoring, and studies of the geological past that temporal trend analyses are possible that provide indications of future change. This coupled with knowledge of natural processes may indicate adaptation strategies that are 'environmentally friendly'. Several participants noted that funding archival storage facilities was a challenge, they were not inexpensive, and providing resources in the face of other demands for financial support was difficult.

In this context, geochemists, in particular, have a role to ensure that national and international standards are maintained so that data from multiple sources nationally are of comparable quality (QA/QC) and appropriately 'level'. From this follows the ability to compile data internationally. Only bodies with national mandates can undertake this task, and many Geological Surveys have taken on this responsibility. In discussions of the technical aspects of QA/QC work examples were shown that demonstrated the value of sample randomization prior to analysis, and careful inspection of data returned to the geochemist from the laboratory.

Many Surveys are facing extensive retirements of staff in the next decade, and recruitment of new staff poses challenges as fewer students are graduating with geoscience degrees. It was also noted that with resource cuts in Surveys in recent years the number of students hired to support studies in the field and laboratory had decreased. Students receiving relevant training form a valuable cadre from which Surveys, and other agencies or industries, can hire competent staff. The consensus was that Surveys should consider it a national responsibility to provide practical training opportunities in order to sustain a supply of adequately trained geoscientists to meet national needs.

A strength of Geological Surveys has been their ground-breaking role in advancing capabilities in analytical techniques and methodologies. These successes have not only led to major progress in exploration for mineral deposits but, through proactive technology transfer to industry, university and OGDs, have had a major impact on other disciplines such as environmental science. The requirement to lower detection limits below background levels, for example, is much more demanding than that needed to monitor waters for compliance to quality guidelines. This scientific leadership is threatened today by lack of funding and loss of expertise through retirements. This can be addressed to a degree by the sharing of sophisticated expensive instrumentation, perhaps through improved cooperation with universities who are, at least in Canada, well funded with respect to equipment but not people. However, it is imperative that Surveys do not lose their expertise in the current state-of-the-art technologies and continue to advance 'routine' methods. Through the use of Quality Assurance (QA) procedures, 'bulk' analytical work can be contracted out to commercial laboratories. However, it is clear, as evidenced by past and present 'round-robin' exercises, that QA analyses must be continually undertaken by the Survey laboratories to ensure the published data meet Survey organization standards. Thus Surveys must both retain their abilities and expertise in the routine analytical technologies, and continue to play a role in major analytical advancements, particularly in the determination of elemental species.

An extension of the above concerns the role of Surveys in the education of school students and the public to the geosciences and geochemistry. It was agreed that public outreach and web sites were important in raising the level of interest in the geosciences, helping convince people of the importance of geoscience as a contributor to society, and stimulating some to pursue careers in geoscience.

6. What do Politicians and Legislators want from Geological Surveys?

The Finnish and Swedish experience was that politicians and legislators wanted maps where they can see that something is good or bad. That places a demand on geoscientists to synthesize their data into simple forms for such 'clients' that focus on cause and effect in the context of a specific issue, i.e. risk or hazard maps, or, here is an area of economic mineral potential and hence employment opportunities.

In the context of geochemistry, the comment was made that now is the time to ensure legislators are aware of the role that geochemistry has in providing the sound science concerning natural processes that permits the establishment of the best possible regulatory frameworks.

There was recognition that there is a need to balance the tensions of 'political' wishes against the long-term needs for geoscience development. A similar tension exists between the demands for applied science now to meet program needs and the need to proactively 'divine' topics that are likely to be 'coming down the line', so that there is a core basis of expertise that permits a rapid and effective response. In order for legislators to continue to regard Surveys as a source of relevant geoscience expertise they have to be able to respond appropriately. To support this requirement Surveys need access to 'futures scenarios', the foresight to select some of the most important areas of early study, and the skill to persuade legislators that this work, that may appear 'blue sky', requires support. Well documented case histories are one way of demonstrating the current worth of past R&D activities.

7. Geochemistry and Health

The opinion was expressed that Medical Geology is dominantly Medical Geochemistry, it is through chemical toxicants or micronutrient deficiencies that the natural environment exercises chronic health effects. Acute events are almost entirely of anthropogenic origin, or of the form of catastrophic hazards due to physical processes, e.g., seismicity or volcanicity.

It follows that the participants believed that geochemistry has a major role to play in some human health issues where there is exposure either by direct contact or ingestion of mineral material, or through the food-chain. There was consensus that these studies must be carried out in close collaboration with medical/veterinary/toxicological/epidemio-logical and nutrition/agricultural scientists in order to gain acceptance of the geoscience contribution. Participants reported that they had the greatest success when working with epidemiologists, medical statisticians and geographers, rather than medical doctors. It was reported that it had taken many years of work with clinicians in Norway before a paper with a geoscience perspective was published in a medical journal.

With the increasing concern of populations and governments over environmental health issues it was considered that collaborative projects with medical and agricultural scientists focussing on the relationship of geology and geochemistry to human health held great potential for demonstrating the relevance of geoscience to an issue of current societal concern. One area of potential collaboration concerns the correlation of regional geochemical survey data with spatial patterns of human and animal health, and food, related phenomena. For example, the USGS has developed relationships with the Center for Disease Control and the Institute for Medical Pathology under a program that is loosely known as Medical Geology. These contacts have led to joint meetings, short courses, and workshops between medical researchers and geochemists who work on trace elements. The results have been dramatic in terms of educational feedback and opening up new lines of inquiry and understanding.

8. Is Geochemistry a science?

The above question was on the original draft agenda. While it was agreed that geochemistry is both a tool and a science in its own right, a diversity of opinion was expressed as to relative balance/importance. The USGS, for example, considers geochemistry very much a science, and that geochemical surveys are simply one approach to getting the necessary information. Other Surveys perceive geochemistry as dominantly a tool; and that, other than executing regional surveys, maximum benefit, exposure and gain can be obtained by working in collaboration with other (geo)scientists who are receptive to the contributions geochemistry can make to their own objectives. To some extent, this appears to reflect resource availability. Smaller and ‘poorer’ geochemistry groups need to reach out to build critical mass and impact, whereas larger better funded agencies, while still needing intellectual collaboration have more resource ‘freedom’ and internal capacity. In any case, the role of geochemistry in Surveys is to provide a better understanding of the processes influencing the environment, and this comes from the ability to interpret acquired data, not just efficiently undertaking the mechanics of survey activities. An important science activity is in the development of geochemical models, and the determination of the validity of proposed models, particularly where they concern environmental issues and the transport and fate of pollutants.

9. Common interests and potential for collaboration

While it was recognized that Surveys have different roles in different countries with varying 'mixes' of resource and environmentally driven projects, and short- and longer-term studies there are many opportunities for collaboration.

Continental-scale and trans-national studies cannot be undertaken without collaboration between Surveys. Vehicles to support such collaboration exist in the context of the International Union of Geological Sciences, e.g., the Working Group on Global Geochemical Baselines, and adherent organizations such as the International Association of Geochemistry and Cosmochemistry. On regional scales, in Europe FOREGS has provided the framework for European geochemical mapping, and in North America the Memorandum of Understanding between the Canadian, Mexican and U.S. Geological Survey organizations provides a similar framework. In Europe, the trans-national structures of the Community (EC) have led to "Regulations" concerning the physical environment; in order that natural processes may be recognized and properly taken into account national Geological Surveys must act together.

Concerns over the environment, toxicants and micronutrients, and the requirement for knowledge of baseline levels of natural occurring substances that are also released by societal utilization, will spur regional/continental geochemical studies to support regulation and decision making. In order to carry out consistent trans-national activities that will yield data that can be integrated will require guidelines (gentle admonition) protocols (firm recommendations) and standards be established. However, for guidelines and protocols to be adhered to with consistency and commitment they have to be developed collaboratively. The FOREGS, Barents and Baltic Soil Survey activities in Europe are examples of successful collaborations. It is most important that Surveys support these collaborative protocol and standard development exercises. The above organizations and frameworks provide the venues and legitimization of these activities, and for the authoritative promulgation of the results.

Participants recommended that protocols should be developed for general sample media groups, e.g., rocks, glacial diamictons, soils, freshwater sediments (stream and lake) and waters (surface and ground). These should include guidelines (ideally firm protocols) for sample collection, preparation, analysis and long-term physical storage.

Where protocols have been developed and successfully applied, e.g., for the FOREGS and Barents surveys, they should be made widely available so that they become attractive to those entering new activities.

Different Geological Surveys have developed varying expertise sets in meeting their national mandates and responsibilities. The potential exists to share this expertise between Surveys, so that when faced with a new challenge a Survey may get 'up to speed' as quickly as possible. FOREGS has a 30 Survey by 25 Activity matrix indicating developed/available expertise.

As the number of Survey geochemists decreases in many countries and critical masses at central offices are lost the role and benefits of regional meetings increase, where at least temporarily critical masses of intellect and experience can focus on issues of common concern.

10. Summation

Participants recognized that geochemistry has a important role to play in Survey activities in the 21st Century. However, as distinct from the 20th Century, environmental issues may eventually become more important than resource issues in sustainable development decision making; in fact this has already happened in some countries. Surveys in countries with active mineral industries that provide employment opportunities for their communities will need to maintain geochemistry expertise concerning mineral exploration, especially the search for deeply buried resources. However, all Surveys will be required, and should take responsibility, to provide natural process expertise so that ecosystem and human health risk assessment and management decisions are properly informed, and that policy and regulation are founded on sound science.

With globalization becoming a feature of the late 20th Century and current times, there will be increasing demands for data and information at global scales to ensure various aspects of 'level playing fields'. Geological Surveys need to ensure that guidelines, protocols and standards are collaboratively developed to ensure that expensively acquired data are compatible and can be integrated into global-scale studies.

To be able to respond in appropriate manners to S&T requirements geochemists, and other geoscientists, should take the opportunities that exist to meet in regional and other gatherings to 'compare notes', share experiences; for example, this Espoo meeting hosted by the GTK. An extension of this is the formation of formal working groups to develop protocols and standards for international adoption.

11. Acknowledgement

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Appendix 1

Examples of Vision and/or Mission Statements:

U.S.A.	"The USGS provides the nation with reliable, impartial information about the earth to minimize the loss of life and property from natural disasters, to manage biological, water, mineral, and energy resources, to enhance and protect the quality of life and to contribute to wise, economic, and physical development"
Finland	"GTK is a leading force in the production and interpretation of geological information and a centre of excellence. Investing in geological information will support sustainable development" and "To create conditions for supporting sustainable raw materials supply and land use"
Canada	"To be, and be recognized to be, a leader in the development, deployment and integration of S&T into policy and decision making by Natural Resources Canada, the federal and provincial governments, industry and other stakeholders"