Global geochemical baselines: Their importance for the mineral industry

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SUMMARY

In 1987, at the time of the previous conference in this series, discussion on the subject of international geochemical mapping was just beginning and the concept of global geochemical baselines was still over the horizon. The progress that has been made in the past decade, and which is reported in this paper, is a reflection of the extent to which the need to standardize geochemical data, and the need to take a global view of all parameters pertaining to the environment, have been recognized. The developments which are taking place will benefit both the mineral industry and every other activity governed or influenced by the earth's surficial geochemistry.

As a result of work which commenced in 1988, recommendations for the establishment of a global geochemical database have been published by UNESCO (Darnley *et al.*, 1995) and widely circulated to national and international institutions. In 1996 these recommendations were endorsed by the UN Committee on Natural Resources as the central component of a new Global Land Monitoring Program (UN, 1996). The UN committee supported the concept for the following reasons:

- the world's present population cannot be sustained without a stable biological environment or without the products of the mining industry;
- both the mineral industry and the biological environment are dependant upon the raw materials contained in and on the earth's surface layer;
- the existing land area must satisfy the continuing demand for more mineral products, for more agricultural production and for more living space;
- sustainable development requires comprehensive knowledge of land surface geochemistry because this is relevant to both economic and environmental management decisions;
- there is presently a huge gap in current environmental monitoring programs in that current programs do not deal with the natural chemical variability of the land surface or with changes brought about by both natural and orthogenic processes.

In order to be useful a global geochemical database must be systematic and standardized. This can be achieved by means of a geochemical reference network of sample sites in a variety of media, which may be compared with geodetic reference points in a topographic survey. The UNESCO report discusses at some length methods for creating a geochemical reference network, the creation of which allows the derivation of geochemical baselines on a continental and global scale. Data from each of the sampling points of the reference network record the geochemical abundances of the elements in a given medium, and the measured values can be joined to form reference surfaces. Each surface defines the geochemical baseline for a given element in a given medium. Element abundances vary from point to point, so the closer the points in the network the more precisely can the true baseline value at any given location be defined.

The specific relevance of a global geochemical reference network and geochemical baselines to the mineral industry can be summarized as follows:

- they provide a datum for verifying and comparing the quality of all exploration geochemistry databases;
- they provide a reference network for environmental monitoring;
- they provide a source of data for public information and education.

There are philosophical as well as practical reasons for stating that standardization in geochemical mapping is overdue. Over the past 300 years progress in most branches of science has been marked by recognition of the advantages of quantifying descriptions and adopting standardized methods and internationally agreed units of measurement. The process of standardization has been more easily achieved in pure than in applied sciences because in the former the field of interest can be conceptually restricted and measured in isolation. In contrast, because of the complexity of the earth's crust, and the variety of approaches that are possible, it has been particularly difficult to introduce standardized methods of measurement into exploration science. Because exploration geochemistry can target specific elements, most investigations in this field have been concerned with the discovery of a narrow range of economic commodities. The systematic acquisition of a broad range of standardized

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generic data has been confined to a relatively small number of national programs. As elaborated in the UNESCO report, even these have had serious omissions and inconsistencies, one compared with another.

It is relevant to note that there are now continental-scale gravity and aeromagnetic data sets and maps because international standardization of gravity and aeromagnetic measurements occurred quite early in the commercial application of these methods, in the 1930s and 1940s respectively. This *de facto* standardisation occurred because acceleration due to gravity and magnetic field strength are clearly defined physical parameters, with limited choice as to the methods of measurement, and instrumentation is easily standardized. The standardization of gamma radiation surveys, which map the distribution of the radioactive elements, took longer to achieve. It required the sponsorship of the International Atomic Energy Agency during the 1970s, to develop and publicize appropriate reporting methods and calibration procedures. Gamma radiation surveys constitute a quasi-geochemical technique, but exploration geochemistry as a whole has lacked standardization. This is particularly serious because of the large number of variables which may influence a given data set, for example, choice of sample medium, method of sample preparation, size fraction, analytical method, method of dissolution (if any), limit of detection, use of standard reference materials and quality assurance protocols, etc. Only in a few countries have government agencies adopted standardized methods within their own territory. Even where nominally similar methods have been used in adjoining countries there have usually been sufficient differences in detailed procedures to invalidate quantitative comparisons. Exploration geochemical surveys undertaken by industry show much greater diversity. Methods have been optimized for particular purposes in specific areas. The acquisition of a systematic multi-purpose database with a variety of long-term applications has not been considered to be economically justified.

The establishment of a global geochemical reference network, as accepted in principle by the UN, provides a means of monitoring and upgrading the quality and significance of all geochemical survey work, irrespective of application, whether it is for exploration or environmental purposes. A comprehensive database can serve as a reference datum against which all subsequent changes in the environment, caused by either natural or anthropogenic factors, can be measured. From an exploration viewpoint it is advantageous to be able to extract the maximum amount of information from any data set. It is advantageous if numerical values obtained from different surveys in different regions can be compared. The use of subtle interpretive criteria, such as element abundance ratios, is only justified if data are derived in a standardized way and if there can be a high level of confidence in the numerical values obtained.

Globalization has become a catchword to describe many contemporary activities and problems, ranging from mining operations to manufacturing to trans-border environmental pollution. Because events in one country can rapidly affect others (for example, Chernobyl), requiring in some instances rapid decisions on remedial action, a global information base is required which contains systematic and standardized data, including geochemical data. From a purely economic viewpoint, because major corporations in the mineral industry are now interested in all parts of the world, it facilitates planning and decision making if basic exploration and environmental background data are available everywhere according to common standards.

In recent years, national regulatory agencies and international commissions, stimulated by public concern, have begun to legislate acceptable safe levels of chemical substances in the environment. The existence of natural variations in the geochemical background has often been overlooked. The deficiencies of existing databases, whether national or regional, result in the fact that the scientific community, schoolteachers, the general public, and legislators, lack necessary information. It is not surprising, therefore, that in the absence of comprehensive data there is a growing list of examples from many countries of public policy being based on erroneous assumptions about the composition of the natural environment. Lack of knowledge leads to bad legislation and unrealistic regulations. Failure to recognize the extent of natural variations can result in legislated “safe levels” below natural background levels, which are unjustified and prohibitively expensive to achieve. Lack of information causes public alarm and unnecessary restrictions upon economic development and employment. Standardized geochemical mapping is needed in order to quantify these spatial variations, evaluate short-term contamination issues and provide a basis to anticipate and monitor the effects of global climatic change. Quantitative baselines are needed to demonstrate that natural background levels vary from place to place, and that pristine nature is not necessarily “hazard free”. Both general taxpayers and the mineral industry suffer the consequences of lack of data. According to Thornton (1995), misconceptions regarding metals in the environment are many and varied, for example, that metals only enter the environment from anthropogenic sources and that metals are toxic, regardless of concentration or whether they appear in biologically inert forms. These and other misconceptions have in recent years had a major impact upon the ability of the mining industry to expand or maintain operations in developed countries.

Given the situation summarized above, the work which commenced in 1988 and resulted in the publication of the UNESCO report, has made recommendations based on the following philosophy:

- geochemical phenomena extend across national borders and the related information base has multi-purpose applications and international implications;
- a common primary international geochemical reference network is required;
- this quantitative primary reference network can provide a foundation for the adoption of standardized methods and reference materials for detailed regional or national mapping, and establishment of closer spaced reference points if required;
- specialized local investigations for economic and/or environmental purposes can be quantitatively tied into the international and national networks in order to determine their significance and relevance within a broader context.

It is impossible to condense a 120-page report in this extended summary.

The report reviews the current worldwide status of geochemical mapping; existing methods of geochemical mapping; the concept and requirements for a global geochemical reference network; sample collection and preparation specifications; analytical requirements and standards; gamma radiation methods and their relevance; and data management procedures. A comprehensive appendix contains information to assist readers in developing countries who may not have easy access to supplementary technical literature. In parallel with the publication of the report, a Global Terrestrial Grid map has been prepared (Gustavsson and Everett, 1996) which locates the 160×160 km equal area cells forming the reference network. The grid map has an origin on the equator at the Greenwich meridian. Cells are defined by two parallels of latitude 1.5° (approximately 166 km apart) and by meridians spaced in successive latitudinal bands so as maintain a constant area of 25 600 km^2.

A major obstacle to past action on the issues involved has been the absence of any internationally recognized organization with a mandate to focus on broad geochemical issues. Unfortunately the International Atomic Energy Agency is restricted in its mandate to radioactive elements, but in many ways it contains the requisite mix of technical facilities and international support which are required in order to make progress. If international agencies are unable to find funding to coordinate the work of implementing and monitoring the creation of an international geochemical reference network then recourse will have to be made to users and beneficiaries of the resulting data, including world environmental organizations and the mineral industry. By supporting the conduct of geochemical mapping to recommended international standards, industry could both create goodwill and assist its own operations. In the process it would establish much needed environmental baselines and obtain high sensitivity exploration data. A feature of the recommendations attached to the global baselines project is the emphasis upon obtaining the lowest possible detection limits for all elements. Recent work in China relating to gold exploration has demonstrated the clear advantages of employing methods with a limit of detection below that at which an element is present in nature.

The work on this project has been undertaken for the past nine years under the auspices of the International Geological Correlation Program, a joint creation of the International Union of Geological Sciences and UNESCO, and also under the auspices of the International Association of Geochemistry and Cosmochemistry. The former arrangement is now coming to an end. In 1996 the International Union of Geological Sciences sanctioned the formation of a new Working Group on Global Geochemical Baselines to work towards the implementation of the report's recommendations through continuing scientific investigations and by seeking support from public and private organizations. During the past decade, the greatest progress in implementing the philosophy of the report has taken place in China, where amongst many related activities, extensive field experiments have been conducted to verify new approaches for wide spaced regional surveys, for example, by sampling flood plain sediments of large drainage basins and comparing the results with detailed sampling of low-order streams in the same basins (Xie and Cheng, 1997). Work has commenced in northeastern Brazil where reference network samples have been collected over an area of 650 000 km^2. Brazil is also making a calibrated compilation of its extensive holdings of airborne gamma ray survey data, which will constitute a significant addition to a geochemical database meeting international standards. Following a three year study by a Task Group initiated by the Forum of European Geological Surveys (Plant *et al.*, 1996), national geological organizations in 22 countries have made commitments to begin work in 1997 to implement the UNESCO report's recommendations concerning the establishment of the global reference network within Europe.

These developments, and others now under discussion, are the first steps in the construction of an authoritative global knowledge base concerning the surface distribution of the elements, which will benefit both the mineral industry and mankind as a whole. The UN Committee on Natural Resources, in endorsing the global baselines project, stated (UN, 1996) that "there is an urgent need for its implementation."

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