Olle Selinus

Medical Geology: An Opportunity for the Future

WHY IS GEOLOGY IMPORTANT FOR OUR HEALTH?

Our environment is the entire web of geological and biological interactions that characterize the relationship between life and the planet Earth. Essential and toxic elements in bedrock or soils may become a direct risk for human and animal health and may be the underlying cause of both deficiency and toxicity. Some naturally occurring elements are necessary for our well-being, while others are detrimental to our health. Naturally occurring elements can have detrimental effects on health when ingested in increasing quantities. Metals have always existed and will forever exist, but we cannot avoid the fact that the health of human beings and animals is influenced by metals and other elements in the environment. Geological processes along with human activities of all kinds have redistributed these from sites where they are fairly harmless to places where they adversely affect humans and animals.

Geology may appear far removed from human health. However, rocks are the source of all the naturally occurring chemical elements found on the Earth. Many elements in the right quantities are essential for plant, animal, and human health. Most of these elements enter the human body via food and water in the diet and through the air that we breathe. Through the weathering processes, rocks break down to form soils on which crops and animals that constitute the food supply are raised. Drinking water moves through rocks and soils as part of the hydrological cycle. Much of the dust and some of the gases present in the atmosphere are the result of geological processes. Hence, a direct link exists between geochemistry and health due to ingestion and inhalation of chemical elements.

Volcanism and related igneous activities are the principal processes that bring elements to the surface from deep inside the Earth. For example, the volcano Pinatubo ejected in just over 2 d in June 1991, about 10 billion tonnes of magma and 20 million tonnes of SO_2 and the resulting aerosols influenced the global climate for 3 y. This event alone introduced 800 000 tonnes of zinc, 600 000 tonnes of copper, and 1000 tonnes of cadmium to the surface environment. In addition to this, 30 000 tonnes of nickel, 550 000 tonnes of chromium, and 800 tonnes of mercury were also added to the Earth's surface environment. Volcanic eruptions redistribute some of the harmful elements, such as arsenic, beryllium, cadmium, mercury, lead, radon, and uranium, plus most of the remaining elements, many of which may have still undetermined biological effects. It is also important to realize that there are on average 60 subaerial volcanoes erupting on the surface of the Earth at any given time, releasing various elements into the environment. Submarine volcanism is even more significant than that at continental margins, and it has been conservatively estimated that there are at least 3000 vent fields on the midocean ridges (1). One interesting fact is that about 50% of SO_2 is of natural origin, mainly from volcanoes, and the other 50% is from human sources.

The naturally occurring elements are not distributed evenly across the surface of the Earth, and problems can arise when element abundances are too low (deficiency) or too high (toxicity). The inability of the environment to provide the correct chemical balance can lead to serious health problems. The links between environment and health are particularly important for subsistence populations that are heavily dependent on the local environment for their food supply. Approximately 25 of the naturally occurring elements are known to be essential to plant and animal life in trace amounts, including Ca, Mg, Fe, Co, Cu, Zn, P, N, S, Se, I, and Mo. On the other hand, an excess of these elements can cause toxicity problems. Some elements such as As, Cd, Pb, Hg, and Al have no or limited biological function and are generally toxic to humans.

Many of these elements are known as trace elements because they generally occur in minute ($\mu g\ kg^{-1}$ or ppm) concentrations in most soils. Trace element deficiencies in crops and animals are therefore commonplace over large areas of the world, and mineral supplementation programs are widely practiced in agriculture. Trace element deficiencies generally lead to poor crop and animal growth and to reproductive disorders in animals. These problems often have the greatest impact on poor populations who can least afford nutritional interventions for their animals.

WHY IS THE INTEREST IN MEDICAL GEOLOGY INCREASING?

Certainly, for the past several decades there has been a growing awareness of environmental health issues (2). More and more people in developed and developing countries are becoming aware of the potential health impacts of environmental pollution. By and large these concerns had been focused on industrial contamination. However, there has long been a small but active group of researchers who recognized that natural materials and processes could be as dangerous as the pollution from anthropogenic materials and processes. Perhaps the success in improving air and water quality in many developed countries has given us confidence that we can now tackle nature and mitigate or eliminate the environmental health issues caused by exposure to natural materials (3, 4, 5).

Although geologic factors play key roles in a range of environmental health issues that impact the health and well-being of billions of people worldwide (6), there is a general lack of understanding of the importance of these factors on animal and human health among the general public, the biomedical/public health community, and even within the geoscience community. To assist on improving our understanding of those factors of common interest to the geoscience and biomedical fields, in 1996 the International Union of Geological Sciences (IUGS) commission Cogeoenvironment established an international working group on medical geology led by Olle Selinus of the Geological Survey of Sweden (SGU). The primary aim of the medical geology working group was to increase the awareness of this issue among geoscientists, medical specialists, and the general public. In 2000, a new project was subsequently established by the United Nations Educational, Scientific, and Cultural Organization. The primary aim of the projects were to bring together, at the global scale, scientists working in this field in developing countries with their colleagues in other parts of the world. The International Council of Scientific Unions (ICSU) also sponsored international short courses in this subject, a cooperation involving the SGU, US Geological Survey (USGS), and the US Armed Forces of Pathology (AFIP). In 2006, as a result of the remarkable growth on medical geology issues, a new association was established: the International Medical Geology Association (IMGA) (6, 7, 8).

We believe that the internet has also played a major role in the resurgence of medical geology. The internet has provided the ability to instantly disseminate information to every corner of the world. Graphic color images, announcement of upcoming conferences and new books, publication of research reports, etc. now are within the reach of every person concerned with these issues even in the most remote parts of the planet. An indication of the power of the internet and the rapid growth of medical geology can be seen from the number of medical geology "hits." As of October 2006 "medical geology" produced more than 40 000 hits on the Google search engine, while just a few years ago the hits were measured in the hundreds.

SHORT COURSES: SPREADING THE MESSAGE

With the support of IUGS, USGS, AFIP, SGU, and the host countries, the ICSU money was used to fund many more short courses than had been proposed. These courses have been presented in 30 countries and have been attended by more than one thousand students and professionals with backgrounds in geoscience, biomedical/public health science, environmental science, pathology, geography, engineering, chemistry, etc. The leaders of the short course are Jose Centeno, Bob Finkelman, and Olle Selinus. In addition, local scientists are invited to describe medical geology work going on in their regions, and in some courses students have been encouraged to present their work on medical geology in the form of posters and special papers.

The aim of the short courses is to share the most recent information on the relationship between toxic metal ions, trace elements, minerals, etc. and their impact on the environmental and public health issues. The scientific topics of the course include environmental toxicology; environmental pathology; geochemistry; geoenvironmental epidemiology; extent, patterns, and consequences of exposures to toxic metal ions; and analysis of geologic and biologic materials.

The courses, generally 2 to 3 days in length, are intended for anyone interested in the effects of natural materials and natural geological events on animal and human health. An important objective of the courses is to provide an opportunity for forming contacts and networks between professionals working in different countries and on different aspects of environmental health issues. We have produced a 300 page syllabus and a CD containing the lecture materials used in the short course, as well as supplementary material such as reprints of relevant articles for participants to use in their regions and on their respective disciplines. The use of this course material by participants and students has been highly encouraged, as has the preparation of lectures and other didactic materials.

EDUCATION

The biggest challenge facing medical geology is the integration of geoscience and biomedical public health research, including the availability of funds to conduct research and training activities. The researchers attend separate conferences, subscribe to different journals, and to some degree have different philosophical approaches and speak different languages. A concerted effort by these two communities will bring medical geology to its full potential. Biomedical/public health organizations have demonstrated interest equal to that of the geoscience community. In addition, universities, medical schools, research hospitals, and biomedical professional organizations in different countries have all shown interest in this field, as have chemists, engineers, environmentalists, geographers, etc. (9, 10, 11).

Several books on medical geology have been published in the past few years (12). In 2002 Catherine Skinner and Tony Berger edited *Geology and Health,* the proceedings of a medical geology conference that was held a few years earlier in Uppsala, Sweden (13).

In 2005 Elsevier published *Essentials of Medical Geology* edited by Olle Selinus and six associate editors: Brian Alloway, Jose Centeno, Bob Finkelman, Ron Fuge, Ulf Lindh, and Pauline Smedley. *Essentials of Medical Geology* is composed of scientific contributions from over 60 authors around the world. About 50% are geoscientists and about 50% are physicians, veterinarians, and other scientists (14).

As a book dedicated to the emerging field, *Essentials of Medical Geology* was in November 2005 recognized as a "Highly Commended" title in the public health category by the British Medical Association, one of the most prestigious medical associations in the world. The book is one of the best of all published books in public health in 2005. They bestow awards upon publications "which are deemed to best fulfill the criteria of clinical accuracy and currency and which maintain a high standard of design and production." *Essentials of Medical Geology* was also awarded a second prestigious reward in January 2006. It was one of two winners in the "Geology/Geography" category of the 2005 Awards for Excellence in Professional and Scholarly Publishing. The PSP awards recognize both editorial standards as well as design and production standards. PSP is the Professional Scholar Publishing division of the Association of American Publishers. The book has now thus been recognized in both communities for which it was intended (first by the British Medical Association, and then as a geology resource).

Colleges and universities in several countries (Sweden, Egypt, the United States) have begun to offer credit courses in medical geology using the book *Essentials of Medical Geology*. Students in many countries have expressed interest in attending such courses and even in majoring in medical geology. Scores of graduate students in many countries are currently working on a wide range of medical geology issues, and students are working on medical geology issues for masters and doctorates in several countries including Turkey, Sweden, the United States, Russia, China, and elsewhere. Research Fellowships and postdoctoral studies in medical geology have been offered by the US Armed Forces Institute of Pathology, the US Geological Survey, and the US Department of State.

The Armed Forces Institute of Pathology has also created a medical geology registry that contains information, diagnoses, and tissue and body fluid samples on a range of health problems caused by environmental and natural geologic materials.

These examples are all solid and necessary indications of a very healthy, growing interest in the subject of medical geology.

INTERNATIONAL IMPACT

Interest in medical geology has been demonstrated in virtually every country (15). During the past few years, scientific organizations in Argentina, Australia, Brazil, Canada, China, Chile, Egypt, Great Britain, India, Ireland, Hungary, Japan, Lithuania, Malaysia, Mexico, Monaco, New Zealand, Romania, Russia, South Africa, Sweden, Turkey, the United States, Uruguay, Venezuela, and Zambia have sponsored one or more medical geology short courses. In many of these countries multiple organizations have sponsored the courses, and many of these organizations have provided financial or logistical support to ensure their success. Similar courses have been requested by organizations in Cyprus, Nigeria, Portugal, Italy, Kenya, Tanzania, Pakistan, Thailand, Taiwan, and Indonesia. Organizations and individuals around the world are taking initiatives to

Figure 1. International Medical Geology Association.

develop medical geology programs and activities. This is particularly the case in Brazil, Turkey, Australia, Canada, Eastern Africa (Kenya and Tanzania), and South Africa, and Russia.

Other national and international organizations have created committees or divisions dedicated to medical geology. The latest is the Geological Society of America, which, at its annual meeting in the fall of 2005, created the Geology and Health Division. During the past 5 y there have been at least six technical sessions and symposia devoted to medical geology at the Geological Society of America annual meeting and regional meetings and dozens of similar sessions at local, regional, and international meetings around the world. Medical geology sessions have been organized at major medical and pathology conferences including the International Academy of Pathology, the International Symposium on Metal Ions in Biology and Medicine, and the US Annual Force Health Protection Conference.

INTERNATIONAL MEDICAL GEOLOGY ASSOCIATION (IMGA)

To respond to the needs of this growing discipline, a new association has been created, the International Medical Geology Association (IMGA) (Fig. 1). The Association was originally launched in Florence in 2004 at the 32nd International Geologic Congress. Since its creation, the association has attracted over 1000 corresponding members from about 70 countries. To better serve the regional needs of our members, regional divisions on medical geology are being formed in South America, Southern Mediterranean, Asian subcontinent, sub-Saharan Africa, North America, etc. A dynamic website (www.medicalgeology.org) has been created containing information on current activities in medical geology. Current and past issues of the organizational newsletter can be downloaded from the site.

The IMGA will also have regional councillors who will represent IMGA in different parts of the world. We have appointed six councillors to represent the broad geographic distribution of medical geology and the wide range of disciplines that are embraced by this topic. Current regional councillors are listed on the website.

Medical geology regional divisions shall also be formed to encourage broad participation in medical geology research, training, and education and to disseminate medical geology information in their respective regions.

INTERNATIONAL YEAR OF PLANET EARTH

The ultimate example of organizational support may be the United Nation's proclamation in December of "The International Year of Planet Earth." The initiative will seek to raise the awareness and role of the Earth sciences in society in the minds of politicians, decision-makers, the media, and the general public. A significant component of this important initiative will be promoting awareness, providing education, and supporting research on a medical geology theme referred to as Earth and Health.

The specific aim of the International Year of Planet Earth is to demonstrate new and exciting ways in which Earth sciences can help future generations meet the challenges involved in ensuring a safer and more prosperous world.

The achievement of this aim will be supported by two major programs

(i) Outreach Program including educational ventures at all levels

(ii) Science Program concentrating on "big issues" of complex interaction within the Earth system and its long-term sustainability.

Medical geology will thus be one of the ten topics within the Year of Planet Earth. The year will be a triennium between 2007 and 2009. Medical geology is also one of the five topics within the GeoUnion initiative.

AN OPPORTUNITY FOR THE FUTURE

It is always risky to attempt to predict what the future holds. However, we are confident that the future for medical geology looks promising. The book, *Essentials of Medical Geology,* has received an overwhelmingly positive response. The reviews have been uniformly positive, and the first printing has nearly sold out in less than a year. The book will stimulate the teaching of medical geology in colleges and universities. The medical geology short courses will continue to attract enthusiastic medical geologists and future students. The International Medical Geology Association should provide a stable platform for the exchange of ideas and dissemination of information. The International Year of Planet Earth will be of great importance not only concerning outreach but also in funding medical geology research all over the world. The wide range of other medical geology activities enumerated above should maintain enthusiasm and momentum for the next few years. Medical geologists are at the forefront to demonstrate that what we have to offer will indeed benefit society by helping to improve the quality of life for people around the world.

References and Notes

1. Garrett, R.G. 2000. Natural sources of metals in the environment. *Human and Ecological Risk Assessment 6*, 945–963.
2. Låg, J. (ed). 1990. *Geomedicine*. CRC Press, Boca Raton, Florida.
3. Finkelman, R.B., Skinner, H.C.W., Plumlee, G.S. and Bunnell, J.E. 2001. Medical geology. *Geotimes 46*, 20–23.
4. Selinus, O. 2002. Medical Geology: Method Theory and Practice. In: *Geoenvironmental Mapping*. Bobrowsky, P. (ed). Balkeema Press, Lisse, Abington, Exton, Tokyo, pp. 473–496.
5. Selinus, O.S. 2004. Medical geology: an emerging specialty. *Terrae 1*, A1–A8.
6. Bowman, C., Bobrowski, P.T. and Selinus, O. 2003. Medical geology: new relevance in the earth sciences. *Episodes 26*, 270–278.
7. Berger, A., Selinus, O. and Skinner, C. 2001. Medical geology—an emerging discipline. *Episodes 24*, 43–44.
8. Bunnell, J.E. 2004. Medical geology: emerging discipline on the ecosystem-human health interface. *EcoHealth 1*, 15–18.
9. Ceruti, P., Davies, T. and Selinus, O. 2001. GEOMED 2001—medical geology, the African perspective. *Episodes 24*, 268–270.
10. Dissanayake, C.B. and Chandrajith, R. 1999. Medical geochemistry of tropical environments. *Earth Sci. Rev. 47*, 219–258.
11. Dissanayake, C. 2005. Of stones and health: medical geology in Sri Lanka. *Science 309*, 883–885.
12. Selinus, O. and Frank, A. 1999. Medical geology. In: *Environmental Medicine*. Möller, L. (ed). Joint Industrial Safety Council, Stockholm, pp. 164–183.
13. Skinner, H.C.W. and Berger, A.R. (eds). 2003. *Geology and Health—Closing the Gap*. Oxford Press, Oxford, 179 pp.
14. Selinus, O., Alloway, B., Centeno, J.A., Finkelman, R.B., Fuge, R., Lindh, U. and Smedley, P. (eds). 2005. *Essentials of Medical Geology*. Elsevier, Amsterdam.
15. Earthwise. 2001. Geology and health. *Br. Geol. Surv. 17*, 6.

Olle Selinus Geological Survey of Sweden PO Box 670, 75128 Uppsala, Sweden
olle.selinus@sgu.se