1

Linking Health to Geology

Antony R. Berger

What Is Medical Geology?

In staking the ground for any new field of science, its distinct character needs to be established. In our opinion, the already large literature on geology and health, including the chapters in this volume, provide two clear arguments for distinctiveness. **First**, medical geology extends the primary concern of geologists with the interactions between rocks, soils, water, and air to the effects of these interactions on the health of humans and other living organisms. Though one focus of medical geology is the search for the origins of disease in the natural geological background, there is also interest in the obvious benefits that the major, minor, and trace elements and the essential molecules found in soils, surface, and groundwater, and in the air we breathe, bring to health and well-being. **Second**, this new field is truly cross-disciplinary; it requires the melding of two distinct research efforts, the one focused on geology, with all its subdisciplines, and the other on living forms. Different viewpoints can be myopic, and to increase understanding of the health implications of the natural background requires the involvement not only of a wide range of earth scientists, but also of researchers and practitioners in medicine, dentistry, veterinary science, biology, botany, agriculture, and ecology, among others.

From the viewpoint of the life scientists, medical geology could be regarded as a subdivision of "environmental medicine" (Möller 2000). This increasingly important aspect of medicine includes consideration of airborne pathways of disease, ozone depletion, algal blooms, the organohalogens, and mycotoxins found as part of the 'ecology' of the built environment (buildings, factories). In general, the purview is any factor in the natural or human environment that affects health. The term "geomedicine" has been used extensively, especially by the late J. Låg (1990). However, unlike the well-established fields of geophysics and geochemistry, in which physics and chemistry are applied to geology, the new field is clearly not about the relevance of medical principles to geology. Rather, it is concerned with the application of geological knowledge and techniques to a more integrated approach to public health. Moreover, as pointed out in the Uppsala meeting, geomedicine seems unlikely to gain acceptance among medical professionals, who use a range of adjectives and modifiers to indicate specialities such as orthopedic medicine, nuclear medicine, and family medicine. The popular current alternative name is "medical geology," as in engineering geology, Quaternary geology, or even military geology.

As long as the new field is being driven from the earth sciences, medical geology seems to fit the bill well enough. It parallels the well-established field of medical geography, which includes the geographic factors of virtually any disease or public health issue (Meade and Earickson 2000). Whatever the final name chosen, medical geology can be described as "the study of the linkages between natural geological factors and the health and well-being of humans and other living organisms." Note the inclusion of nonhuman portions of the biosphere whose health is essential to human survival. This is a slightly modified version of the definition being used by IGCP Project 454 and the IUGS Working Group on Medical Geology. Although it excludes plants and animals, a somewhat more concise explanation is that medical geology is the study of the "public health impacts of geological materials and processes." According to this view, medical geology includes "identifying and characterizing natural and anthropogenic sources of harmful materials in the environment, learning how to predict the movement and alteration of chemical, infectious, and other disease-causing agents over time and space, and understanding how people are exposed to such materials and what can be done to minimize or prevent such exposure" (see <http://www.ecosystemhealth.com/hehp/groups.htm>).

On Crossing Over Discipline Boundaries

This book extols the virtues of cross-disciplinary research in reducing environmental threats to health and well-being. E.O. Wilson (1998a) discusses some of the ground to be explored between the natural and social sciences, using the term 'consilience' to refer to "the interlocking of causal explanations across disciplines." His argument can perhaps be extended to view the boundary between medicine and geology, with all their subfields, not as a wall, but as "a broad, mostly unexplored domain of causally linked phenomena" (ibid. p. 2048; see also Wilson 1998b). For Wilson, the central question of social science is the linkage between genetic and cultural evolution. There is an analogy in the linkage between geology and medicine. Since what we ingest has surely been a major factor in how we have evolved, and since food and drink, which are basic to culture, have as their ultimate source the earth, its materials and processes, then one may expect that crossing over from geology to medicine will contribute to understanding this linkage. Seeing ourselves, like other species, as part of the geological continuum may provide insights about our relationship with the environment, and in turn influence the way we act towards the nonhuman, natural world. An exploration of the medicine-geology divide may help to reconceptualize both the beneficial and the harmful sides of the natural world and its processes, provide a better understanding of the "physical basis of human nature, down to its evolutionary roots and genetic biases" (Wilson 1998a, p. 2049), and yield insights on ways to diagnose and manage some of the global crises.

Frodeman et al. (2001) point out that there is now no field of study that takes as its origin understanding the relationship between the disciplines. Although new disciplines commonly spring from interdisciplinary ventures, once formed they are themselves liable to set up new discipline boundaries, which can in turn block further crossovers. They argue that crossover studies can also advance the different disciplines involved. To most people, medicine and geology seem very odd bedfellows, the former dealing with healing people, the latter with rocks and minerals and the distant past. Could it be that exploring the wide gap between them might bring new insights into what counts as knowledge?

If so, the development in the coming years of this very diverse field might provide an epistemological experiment well worth following. Perhaps some future student of consilience will turn back to the beginnings of the twenty-first century for an example of a new interdisciplinary field here striving to be born.

But there is also a dilemma, for interdisciplinarity is very much a two-way street. Yet, medical geology is being driven at the outset mainly from the earth sciences, and especially from geochemistry. The cry is "If only the medical experts would listen to us, we could resolve many serious problems." Though it is becoming somewhat more common today for geoscientists, epidemiologists, ecologists, and veterinary researchers to cooperate in identifying causes of diseases, it has not been easy to attract medical researchers to cooperative efforts. Medicine concentrates first and foremost on relieving pain and suffering, so that it is necessary to demonstrate how geological information can benefit patients. The review of medical geology by Selinus and Frank (2000) provides many examples of how this is being done, and the present volume also contributes to this understanding.

Why Has It Taken So Long?

If the relationship between rocks, water, soils, and health is so important, and if its antecedents are so ancient — natural salt for human consumption goes back into the dim recesses of history — why hasn't the crossover advanced further? A partial answer may lie in the organizational barriers to interdisciplinary research. Within the earth sciences, linkages are generally strong between many subfields, such as hydrology and hydrogeology, for there are few sharp boundaries between the behavior of surface and subsurface water. However, soils are generally regarded by geologists as within the purview of agriculture and, thus, outside their range of interests. The traditional focus in pedology has been on the descriptive side of soils, such as taxonomy, soil profiles, and catenas. However, the present focus on environment and health issues reinforces the importance of soil as the membrane between rocks and most living organisms, comparable in a sense to the walls of cells, which act as gatekeepers for signals from the rest of the body.

The many separate societies with competing research projects and goals within the geoscience community, while providing for organizational diversity, may also act as a barrier to working across disciplinary boundaries. For example, the International Association of Geochemistry and Cosmochemistry has a working group on medical geology. There is a long-established Society for Environmental Geochemistry and Health, and several other international earth science groups have activities related to health issues, including the International Association for Volcanology and Chemistry of the Earth's Interior, and the International Association of Hydrological Sciences. Oddly enough, the very large and international Society for Environmental Toxicity and Chemistry, though dealing with many of the concerns of medical geology, does not list geology or any of its major subfields among the many disciplines it embraces. Until recently the major agencies funding scientific research have made crossing from one discipline to another rather difficult, though the National Science Foundation (U.S.) and the National Research Council (Canada) have recently signaled the importance of multidisciplinary research.

Are Silent Geochemical Threats Natural Hazards?

There can be no doubt that certain naturally occurring materials, elements, and chemicals can be harmful to human, animal, and plant health: toxic elements in groundwater, the "poisoning" effect of natural heavy metals on vegetation, or deficiencies of essential elements in food crops. The spatial association between health hazards and geochemical "anomalies" that reflect certain rock types and mineral deposits is wellknown, as in the case of radon (Brookins 1990). In Norway, where authorities have tried to encourage greater use of groundwater as a cheap, high-quality alternative to surface water, more than 50% of all bedrock wells exceed recommended drinking water limits for one or more health-related parameters, particularly radon and fluoride (Banks et al. 1998). Hazards to health in all these cases stem from natural conditions that may be pervasive and temporally continuous, or that may vary in time and space with changes in climate, erosion patterns, volcanicity, or the chemical composition of air or surface and groundwater.

It is, thus, rather surprising that the very active and interdisciplinary study of natural hazards, which has its own extensive scientific and policy literature and many national and international agencies and programs, generally does not seem to include consideration of dangers to health from non-anthropogenic chemicals and reactions in soils, water, and air. Such geogenic hazards are well illustrated in the extensive literature on environmental geochemistry (Appleton et al. 1996, Bowie and Thornton 1985). The UN Disaster Relief Office has defined natural hazards broadly as "the probability of occurrence within a specified period of time and within a given area of a potentially damaging phenomenon" (UNDRO 1982), and a number of publications also include hazards from geological materials (e.g. Nuhfer et al. 1993, Guo 1991). Yet, for the most part, the literature on natural hazards ignores the kind of "silent" threats to health that are standard components of the natural environment (Bryant 1991, Burton et al. 1993, Chapman 1994, Tobin and Montz 1997). Even some of the key books on medical geography and epidemiology have very little discussion of the actual or potential effect on health of natural geochemical hazards in rocks, soils, and water (e.g. Howe 1997, Meade and Earickson 2000). Perhaps it is the temporal dimension of geochemical hazards that has kept them distinct from the standard literature on natural hazards, which most hazards workers link to "events," those with obvious beginnings, middles, and ends, and usually quite short — less than a season, a week or a day. Yet those who include biological threats, such as malaria and schistosomiasis (Chapman 1994), in their discussion of natural hazards, clearly extend the temporal perspective to essentially continuous hazards.

The bulk of the literature on natural hazards discusses them solely in terms of their effect on humans and society. As Gilbert White, the pioneer researcher in this field put it, "by definition, no natural hazard exists apart from human adjustment to it" (1974, p.3). For Burton and Kates (1964), natural hazards are those components of "the physical environment harmful to man and caused by forces extraneous to him." Doornkamp (1989) defines a geohazard as one of a "geological, hydrological or geomorphological nature, which poses a threat to man and his activities." This anthropocentric position seems to be echoed by many contemporary writers on natural hazards and disasters. But from a biospheric perspective that recognizes harm done to organisms and even whole ecosystems, the scope of natural hazards extends well beyond human society. There is probably no greater hazard than that caused by the impact of a comet or asteroid, of the sort that hit the Earth at various times in the distant geological past, resetting the evolutionary clock. At the other end of the scale there are numerous examples of the harmful effects of toxic elements in soils and water on animals and fish (e.g., McCall et al. 1966). The ecological (and the mineral exploration) literature describes many situations where plant growth has been retarded by the presence of various chemicals that inhibit growth, structure, or normal plant functions, and where plants act as accumulators of elements harmful to grazing animals. Medical geology extends concerns to the health of animals and vegetation, and thus may help to balance anthropocentric attitudes toward the environment and to stress continuities and crossovers within the biosphere.

Medical Geology and Environmental Management Issues

Turning now to practical applications, medical geology can help to develop guidelines for managing environments where high or low natural background levels of elements, compounds, and minerals in rocks, soils, and water pose a threat to human, plant, or animal health. In doing so, it might be helpful to develop a simple taxonomy of geomedical hazards, as has been done through the geoindicator approach (Berger and Iams 1996) for rapid and dynamic geological processes, some of which can also affect health. These include:

- Increases in sediment erosion and transport, which can uncover toxic wastes deposited earlier ("chemical time bombs")
- Permafrost and gas-hydrate melting, which can lead to methane degassing and influx of insects and diseases
- Changes in groundwater and surface water quality resulting from accelerated erosion, deforestation, pollution, river diversion, groundwater mining
- Drop in lake levels and increase in salinity causing loss of water supplies and increase in airborne particulates
- Catastrophic natural events — landslides and avalanches, earthquakes, tsunamis, and volcanic eruptions, with many effects on settlements, water, soils, air quality

Such a classification could be valuable to environmental planners and the general public, especially if it identified the relevant pathways from source to organism, and distinguished harmful chemicals of natural origin from those due to human actions such as industrialization, urbanization, and waste disposal. If this is not done, serious policy issues can arise.

For example, artisanal gold miners have been criticized severely for being careless with mercury, and there have been many efforts to reduce its usage and to prevent its loss to the environment where it constitutes a health hazard. However, geochemical research shows that much of the mercury around placer gold mining operations in the Tapajós basin of Brazil (Telmer et al. 2000) and in the Rio Béni basin of Bolivia (Maurice-Bourgoin et al. 1999) is bound to suspended sediments eroded from gold-bearing soils that were high in natural Hg long before the advent of humans. Reducing mercury pollution of the rivers and streams would thus require a reduction of placer operations, and not merely a decrease in the use of Hg in gold recovery. The importance of understanding the pathways taken by natural contaminants is clear.

The general public seems to take the "anthropoblamist" view that high concentrations of harmful metals and chemicals must be the result of human activities such as industry, energy generation, and waste disposal. In Canada, for example, a common opinion is that metals in the soils and waters of remote areas come from the long-range atmospheric transport of particulates emitted from smelters, power plants, and waste incinerators. Yet detailed studies of the geochemistry of waters, soils, and bedrocks show that elevated levels of some potentially toxic elements are due to local geological conditions and were present before anthropogenic disturbance of the environment (Rasmussen et al. 1998). Of course, human activities frequently induce changes in natural geochemical backgrounds. Soil pH in parts of Finland has decreased from neutral to 3–4 within 40 to 60 years as a result of reforestation of formerly agricultural fields, with the result that heavy metals like Co, Cr, and Cu, have become more bioavailable and harmful to biota (Lahdenpera 1999). Thirty years of careful monitoring in Finland have shown marked changes in groundwater quality, especially as a result of acidification in the 1970s and 1980s from both natural and human inputs (Backman et al. 1999).

These broad considerations emphasize the need to understand the linkages between the natural geological background and health in order to gain a proper understanding of geochemical cycling and the natural phenomena that contribute to it. A major challenge is to find ways to distinguish between natural inputs, which may not be manageable, and human-induced ones that are. The emerging field of medical geology is poised to make an important contribution to this effort.

References

Appleton, J.D., R. Fuge and G.J.H. MCCall (eds) 1996. Environmental geochemistry and health with special reference to developing countries. London: Geological Society, Special Publication 113, 264p.

Backman, B., P. Lahermo, U. Vaisanen, T. Paukola, R. Juntunen, J. Karhu, A. Pullinen, H. Raino & H. Tanskanen 1999. The effects of geological environment and human activities on groundwater in Finland. The results of monitoring in 1969–1996. Geological Survey of Finland Report of Investigations 147, 155–167.

Banks, D., A.K. Midtgard, G. Morland, C. Raimnan, T. Strand, K. Bjorvatn & U. Siewers 1998. Is Pure Groundwater Safe to Drink?: Natural Contamination of Groundwater in Norway. Geology Today, May–June, 104–113.

Berger A.R. & W.J. Iams 1996. Geoindicators. Assessing rapid environmental changes in earth systems. Rotterdam: A.A. Balkema, 466p.

Bowie, S.H.U. and I. Thornton (eds) 1985. Environmental geochemistry and health. Boston: D. Reidel, 140p.

Brookins, D.G. 1990. The indoor radon problem. New York, Columbia University Press, 229p.

Bryant, E. 1991. Natural hazards. Cambridge: Cambridge University Press, 294p.

Burton, I. & R.W. Kates 1964. The perception of natural hazards in resource management. Natural Resources Journal vol. 3, 412–414

Burton , I., R.W. Kates and G.F. White. 1993. The environment as hazard (Second edition). New York: The Guilford Press, 293p.

Chapman, D. 1994. Natural hazards. Melbourne: Oxford University Press, 174p.