Preface

All substances are poisons; there is none which is not a poison. The right dose differentiates a poison and a remedy.

Paracelsus (1493–1541)

Medical geology is the science dealing with the relationship between natural geological factors and health in humans and animals and with understanding the influence of ordinary environmental factors on the geographical distribution of such health problems. It is a broad and complicated subject that requires interdisciplinary contributions from various scientific fields if its problems are to be understood, mitigated, or resolved. Medical geology, which focuses on the impacts of geologic materials and processes (i.e., the natural environment) on animal and human health, can be considered as complementary to environmental medicine. The field of medical geology brings together geoscientists and medical and public health researchers to address health problems caused or exacerbated by geologic materials such as rocks, minerals, and water and geologic processes such as volcanic eruptions, earthquakes, and dust.

Paracelsus defined a basic law of toxicology: Any increase in the amount or concentration of elements causes increasing negative biological effects, which may lead to inhibition of biological functions and, eventually, to death. However, despite the harmful effects of some elements, others are essential for life. Therefore, deleterious biological effects can result from either increasing or decreasing concentrations of various trace elements. Thus, as with many aspects of life, either too much or too little can be equally harmful. All of the elements that affect health are found in nature and form the basis for our existence as living creatures. The periodic table of elements, as an indicator of the roles played by the elements in the biosphere, is the basis for our understanding (Figure 1).

The writings of Hippocrates, a Greek physician of the Classical Period, demonstrate how far back our basic knowledge extends:

Whoever wishes to investigate medicine properly, should proceed thus....We must also consider the qualities of the waters, for as they differ from one another in taste and weight, so also do they differ much in their quality.

Hippocrates (460–377 BC)

Hippocrates held the belief that health and "place" are related to ancient origin. Knowledge of specific animal diseases also originated long ago. Even in Chinese medical texts of the third century BC, cause-and-effect relationships are found. Unfortunately, most such observations were lost because they were never written down. As the science grew, many previously unknown relationships began to be understood and a new scientific field evolved: medical geology. This book covers the essentials of our knowledge in this area.

Geology and Health

Geology may appear far removed from human health. However, rocks and minerals comprise the fundamental building blocks of the planet and contain the majority of naturally occurring

$_{1}$H																$_{2}$He
$_{3}$Li	$_{4}$Be											$_{5}$B	$_{6}$C	$_{7}$N	$_{8}$O	$_{9}$F	$_{10}$Ne
$_{11}$Na	$_{12}$Mg											$_{13}$Al	$_{14}$Si	$_{15}$P	$_{16}$S	$_{17}$Cl	$_{18}$Ar
$_{19}$K	$_{20}$Ca	$_{21}$Sc	$_{22}$Ti	$_{23}$V	$_{24}$Cr	$_{25}$Mn	$_{26}$Fe	$_{27}$Co	$_{28}$Ni	$_{29}$Cu	$_{30}$Zn	$_{32}$Ga	$_{32}$Ge	$_{33}$As	$_{34}$Se	$_{36}$Br	$_{36}$Kr
$_{37}$Rb	$_{38}$Sr	$_{39}$Y	$_{40}$Zr	$_{41}$Nb	$_{42}$Mo	$_{43}$Tc	$_{44}$Ru	$_{45}$Rh	$_{46}$Pd	$_{47}$Ag	$_{48}$Cd	$_{49}$In	$_{50}$Sn	$_{51}$Sb	$_{52}$Te	$_{53}$I	$_{54}$Xe
$_{55}$Cs	$_{56}$Ba	57-71	$_{72}$Hf	$_{73}$Ta	$_{74}$W	$_{75}$Re	$_{76}$Os	$_{77}$Ir	$_{78}$Pt	$_{79}$Au	$_{80}$Hg	$_{81}$Tl	$_{82}$Pb	$_{83}$Bi	$_{84}$Po	$_{85}$At	$_{86}$Rn
$_{87}$Fr	$_{88}$Ra	89-103	$_{104}$Db	$_{105}$Jo	$_{106}$Rf	$_{107}$Bh	$_{108}$Hn	$_{109}$Mt	110	111							
		$_{57}$La	$_{58}$Ce	$_{59}$Pr	$_{60}$Nd	$_{61}$Pm	$_{62}$Sm	$_{63}$Eu	$_{64}$Gd	$_{65}$Tb	$_{66}$Dy	$_{67}$Ho	$_{68}$Er	$_{69}$Tm	$_{70}$Yb	$_{71}$Lu	
		$_{89}$Ac	$_{90}$Th	$_{91}$Pa	$_{92}$U	$_{93}$Np	$_{94}$Pu	$_{95}$Am	$_{96}$Cm	$_{97}$Bk	$_{98}$Cf	$_{99}$Es	$_{100}$Fm	$_{101}$Md	$_{102}$No	$_{108}$Lr	

Figure 1 Periodic table illustrating major elements (*pink*), minor elements (*blue*), trace elements (*yellow*), and noble gases (*gray*) in the biosphere. Those in green are essential trace elements. Known established toxic elements are shown in *red*

chemical elements. Many elements are essential to plant, animal, and human health in small doses. Most of these elements are taken into the human body via food, water, and air. Rocks, through weathering processes, break down to form the soils on which crops and animals are raised. Drinking water travels through rocks and soils as part of the hydrological cycle and much of the dust and some of the gases contained in the atmosphere are of geological origin. Hence, through the food chain and through the inhalation of atmospheric dusts and gases, human health is directly linked to geology.

The volcanic eruption of Mount Pinatubo is a splendid example of the dramatic effects of geology. Volcanism and related activities are the principal processes that bring elements to the surface from deep within the Earth. During just two days in June 1991, Pinatubo ejected 10 billion metric tonnes of magma and 20 million tonnes of SO_2; the resulting aerosols influenced global climate for three years. This single event introduced an estimated 800,000 tonnes of zinc, 600,000 tonnes of copper, 550,000 tonnes of chromium, 100,000 tonnes of lead, 1000 tonnes of cadmium, 10,000 tonnes of arsenic, 800 tonnes of mercury, and 30,000 tonnes of nickel to the surface environment. (Garrett, R.G., 2000). Volcanic eruptions redistribute many harmful elements such as arsenic, beryllium, cadmium, mercury, lead, radon, and uranium. Many other redistributed elements have undetermined biological effects. At any given time, on average, 60 volcanoes are erupting on the land surface of the Earth, releasing metals into the environment. Submarine volcanism is even more significant than that at continental margins, and it has been conservatively estimated that at least 3000 vent fields are currently active along the mid-ocean ridges.

Goal and Approach

Because of the importance of geological factors on health and the widespread ignorance of the importance of geology in such relationships, in 1996 the International Union of Geological Sciences (IUGS) commission COGEOENVIRONMENT (Commission on Geological Sciences for Environmental Planning) established an International Working Group on Medical Geology with the primary goal of increasing awareness of this issue among scientists, medical specialists,

and the general public. In 2000 the United Nations Educational, Scientific, and Cultural Organization (UNESCO) became involved through a new International Geological Correlation Programme (IGCP) project 454 Medical Geology. Project 454 brings together, on a global scale, scientists working in this field in developing countries with their colleagues in other parts of the world and stresses the importance of geoscientific factors that affect the health of humans and animals. In 2002 the International Council for Science (ICSU) made it possible to put together international short courses on this subject, a cooperation involving the Geological Survey of Sweden, US Geological Survey, and the US Armed Forces Institute of Pathology in Washington, DC. The aim of these short courses, which are offered all over the world, is to share the most recent information on how metal ions and trace elements impact environmental and public health issues. The scientific topics of the courses include environmental toxicology; environmental pathology; geochemistry; geoenvironmental epidemiology; the extent, patterns, and consequences of exposures to metal ions; and analysis. Areas of interest include metal ions in the general environment, biological risk-assessment studies, modern trends in trace-element analysis, and updates on the geology, toxicology, and pathology of metal ion exposures.

Because of this increasing activity and interest in this field, we decided to write a book that could be used both as a reference and as a general textbook. Our goal is to emphasize the importance of geology in health and disease in humans and animals. The audience of the book consists of upper division undergraduates, graduate students, environmental geoscientists, epidemiologists, medics, and decision makers, but, we have also strived to make the book interesting and understandable to environmentally conscious members of the general public.

There are important relationships between our natural environment and human health. Our approach is to integrate these two fields to enable better understanding of these often complex relationships. All chapters have numerous cross-references not only among the other chapters but also to related reading.

Sectional Plan

Chapter 1 gives a brief history of medical geology. It is not intended to be an exhaustive overview; instead our overview highlights some important cases in the development of the science of medical geology.

The subsequent material is presented in four sections, each describing different aspects of the subject.

The first section (Chapters 2–8) covers environmental biology. Environmental biology may be characterized by interactions between geological and anthropogenic sources and the kingdoms of life. The geological sources provide life with essential major, minor, and trace elements. In addition, geology provides access to nonessential elements. To influence life, both beneficially and adversely, elements have to be in the environment as well as, in most cases, bioavailable. Therefore this section gives an introduction to the different aspects of environmental biology and provides a foundation for the following sections.

The second section (Chapters 9–20), on pathways and exposures, covers many of the myriad different aspects of medical geology. It has long been said that "we are what we eat"; however, in terms of medical geology we are in fact what we eat, drink, and breathe. The major pathways into the human body of all elements and compounds, whether beneficial or harmful, derive from the food and drink we consume and the air we breathe. The twelve chapters of this section concentrate on the interrelationships among our natural environment, geology, and health. Numerous examples from all over the world are presented on topics ranging from element toxicities and deficiencies, to geophagia, to global airborne dust and give a clear view of the vast importance of the natural environment on our health. After reading these chapters, you should have no doubt that geology is one of the most important, although often neglected, factors in our well-being.

The third section (Chapters 21–25), on environmental toxicology, pathology, and medical geology, covers the medical aspects of medical geology. In recent decades there has been an increasing awareness of the importance of the interaction of mammalian systems with their natural environment. The primary focus has been on understanding exposure to hazardous agents in the natural environment through air, water, and soil. Such appreciation has led to myriad investigations focused on identifying those natural (and sometimes anthropogenic) environmental risk factors that may be involved in the development of human and other animal diseases. These five chapters describe the different effects of elements in our bodies, how geology affects us, and how we can recognize these effects.

The fourth section (Chapters 26–31), on techniques and tools, brings together in a very practical way our knowledge of the different relevant disciplines. Geoscientists and medical researchers bring to medical geology an arsenal of valuable techniques and tools that can be applied to health problems caused by geologic materials and processes. Although some of these tools may be common to both disciplines, practitioners of these disciplines commonly apply them in novel ways or with unique perspectives. In this part we look at some of these tools and techniques.

Finally, we have included three appendices. Appendix A covers international and some national reference values for water and soils. Appendix B lists numerous Web links from Chapters 19 and 26. Appendix C is a large glossary to be used whenever you need a term explained. We have tried to make this glossary as comprehensive as possible but there will of course be some shortcomings. However, the glossary can also be found and downloaded from the Internet (books.elsevier.com/companions); therefore it can be completed with more explanations when needed.

Reference

Garrett, R.G., 2000. Natural sources of Metals in the Environment. *Human and Ecological Risk Assessment*, Vol. 6, No. 6, pp 954–963.

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