

Editors' foreword

“The growing complexity of geoscientific research and the global perspective of modern geosciences demand interdisciplinary and international cooperation on a world-wide scale. ... Because science does not stop at national borders, ... [the subjects] cover almost the entire field of geoscientific research, ranging from interior Earth dynamics to Global Change, natural resources of water, minerals and hydrocarbons, mitigation of natural hazards, or usage and protection of underground space.” L. Stroink, H.-P. Harjes and J. Karte: Coordinated Geoscientific Research in Germany — The *Deutsche Forschungsgemeinschaft* and its Programs to Foster International Cooperation, 2000.

Geological sciences play a major, but often overlooked role with regard to economic development. This is especially true in Central America, currently home to about 40 million people, a number that is projected to increase to nearly 50 million by 2015.

The unique geological setting of Central America — as a natural bridge between the Americas — is dominated by the presence of five tectonic plates and several blocks and terranes. Its position along plate boundaries, subduction zones, and major strike-slip fracture zones results not only in numerous earthquakes and volcanic eruptions, but also in benefits such as interesting mineral deposits, fertile volcanic soils, and an abundance of geothermal and hydroelectric energy resources — all in the midst of a biological and tourist paradise.

Although Central America encompasses a relatively small area (525,780 km²), its geology is both complex and interesting. It contributes fundamentally to our understanding of the geologic history of the Americas and of the Caribbean region, of the role of biogeography in the migration and evolution of species, and of geographic barriers and climate change. It is one of Earth's regions of highest biodiversity and offers a natural laboratory in geology, geophysics, geochemistry, biology, and climatology.

During recent decades, the Central American region has witnessed an unrelenting succession of disasters related to geological processes such as earthquakes, landslides, and tsunamis, and to climatic events such as hurricanes, extreme precipitations, floods, and droughts. These have cost thousands of lives and material losses in the billions of dollars. In the past 35 years alone, between 32,000 and 41,000 people were killed by natural disasters.

Geology and climate have posed constant hazards since the first Amerindians populated Central America more than 13,000 years ago. However, the geological and climate-related risks increased sharply during the last few decades and will continue to grow in the future. Reasons include human activities such as inadequate land use practices, and demographic pressures that force people to live in areas prone to geologic hazards. For example, seismic and volcanic hazards coincide with those areas where most of the region's population is found, aggravating the risk.

Living with risk cannot be avoided, but disaster-reduction programs can limit losses. These include, for example, early warning systems, improved forecasting tools, adequate land-planning and land use, and the establishment and effective control of construction codes.

Geologic hazards need to be better assessed, via improved seismic and volcanic monitoring, and landslide hazard evaluation. Geological risks should be compiled, by category, into hazard maps, which are an indispensable resource for any wise decision-making by authorities attempting to compile construction codes, risk evaluations, emergency rescue plans, adequate land-use plans, etc.

Considering the availability of energy resources as a precondition for any development, Central America has very few fossil fuel resources, but fortunately has huge resources of geothermal energy. Today these provide only 7% of the region's electricity generation. They can be exploited further as an environmentally sound domestic energy source to cover projected electricity demand, which is expected to grow through the year 2020 at an annual rate of 6% thanks to growing populations and expanding economies. Additionally, increased use of geothermal resources would reduce the region's over-dependence on hydroelectric energy sources, which are currently used to produce over 50% of the region's electricity. Hydroelectric resources are influenced by climatic events and hence are neither stable nor reliable, despite which they are now used to meet most of the region's electricity demand. At present, geothermal resources are extremely under-used and marginalized compared to other renewable and conventional energy resources.

The freshwater resources of Central America are becoming increasingly limited and thus are assuming the status of Central America's "*gold*" of the 21st century. Principal reasons for this growing scarcity are increasing contamination of surface waters and their seasonally fluctuating availability. That leaves groundwater resources as the only viable long-term solution for meeting anticipated future demand for drinking water, as well as irrigation water needed for food security. Water, its purification, and its equitable distribution pose great social challenges for Central America. However, the availability of groundwater resources remains unevaluated, making development, protection, and efficient and optimal sustainable use impossible, so that future access of Central American's population to safe water cannot be guaranteed, even though it is a fundamental human need and, therefore, a basic human right.

Implementing needed measures and working against these deficits requires detailed knowledge of geological processes and their interactions with other processes such as climatic events and socioeconomic factors, as well as forecasts of both demographic and economic development. Classical and modern geological studies are needed, involving modern methods and technologies on the ground along with data obtained from airborne and satellite platforms.

National, regional, and international authorities and private-sector participants need to integrate — more than at present — aspects of development involving issues of geological resources and hazards/risks. They should consider both the economic- and development-related benefits that could result from improving hazard mitigation and increasing the sustainability of resources use.

Prerequisite for all these needed improvements is knowledge of basic geological issues and processes such as plate tectonics and kinematics, structural geology, seismology, petrology, and stratigraphy. Geological resources need to be better assessed. Detailed knowledge of hydrogeology and estimates of economically usable groundwater resources, their quality, and their vulnerability, as well forecasts of water demand, are needed. Geothermal resources, especially those of low and middle

enthalpy which have only recently become economically and technically exploitable, need to be evaluated in terms of their potential future use in the frame of development. Geological heritage resources such as volcanoes, volcanic lakes, geothermal springs, and lava and karst caves should be addressed in the frame of economic and social development. In fact, Central America has 11 noteworthy volcanoes, of which three are among the most active in the world. The national parks associated with them receive over half a million visitors annually. Central America is also home to the second largest coral barrier reef on our planet.

That such needs remain unmet has sometimes been blamed on a lack of consideration and awareness on the part of national authorities, but in fact it is mostly a matter of the lack of local capacity and of missing, incomplete, or inefficient institutional and regulatory frameworks, in both the Central American countries themselves and within international aid and financial and technical cooperation agencies. Capacity building, awareness formation, and educational resources and tools are needed to foster in-depth thinking and problem-solving. These will stimulate improved use of local sustainable resources such as geothermal energy, and improved geological hazard mitigation generally, within an integrated and sustainable approach to geological resources and hazards.

We hope this monograph will help us all to rededicate ourselves to wise and responsible use of Central American geological resources, and will let us improve geologic hazard mitigation. Our goal must be to reduce human and material losses for the sake of our children and our grandchildren, and to avoid jeopardizing their future through inept use of natural resources and underestimation of geology-related hazards and risks.

The book aims to address professionals and academics equally — members of the pertinent national, regional, and international geological communities. It is also intended to serve as a resource for key Central American institutions that deal with land-use planning, water resource planning, seismic and volcanic hazard reduction, energy planning, mining, and urban and infrastructure development, and as a guideline for decision- and policy-making and administrative leaders, both in Governments and in international bodies concerned with technical and economic cooperation in developing countries — like those of the United Nations family and the international and regional development banks, financial institutions, donors, etc.

We hope this monograph will become a standard, used by educational institutions, research institutions, and Research and Development establishments involved in the respective issues. The book should prove useful to senior undergraduate and graduate students, professional geologists and geophysicists, engineers, and others working in Central America. Also, it is ideal for anyone looking for a quick, round-up reference on the geology of Central America, whether professional scientists visiting or preparing to do work in the region, or educated lay-persons who are merely interested in geology, landscapes, natural wonders, and long-term history. For them, it can serve either as a self-contained guidebook or as a foundation for further research.

Not least, this book fills a gap in the literature, not only in the geographic sense of linking the Americas, North and South, but it also joins the Greater and Lesser Antilles into the framework of a single larger Caribbean geological history.

The editors

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San José, November 2006