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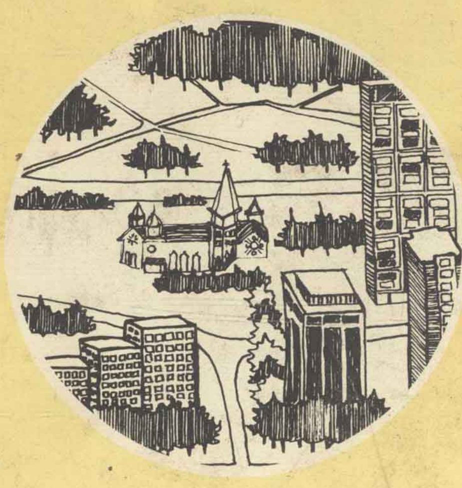

The Earth and Land Use Planning

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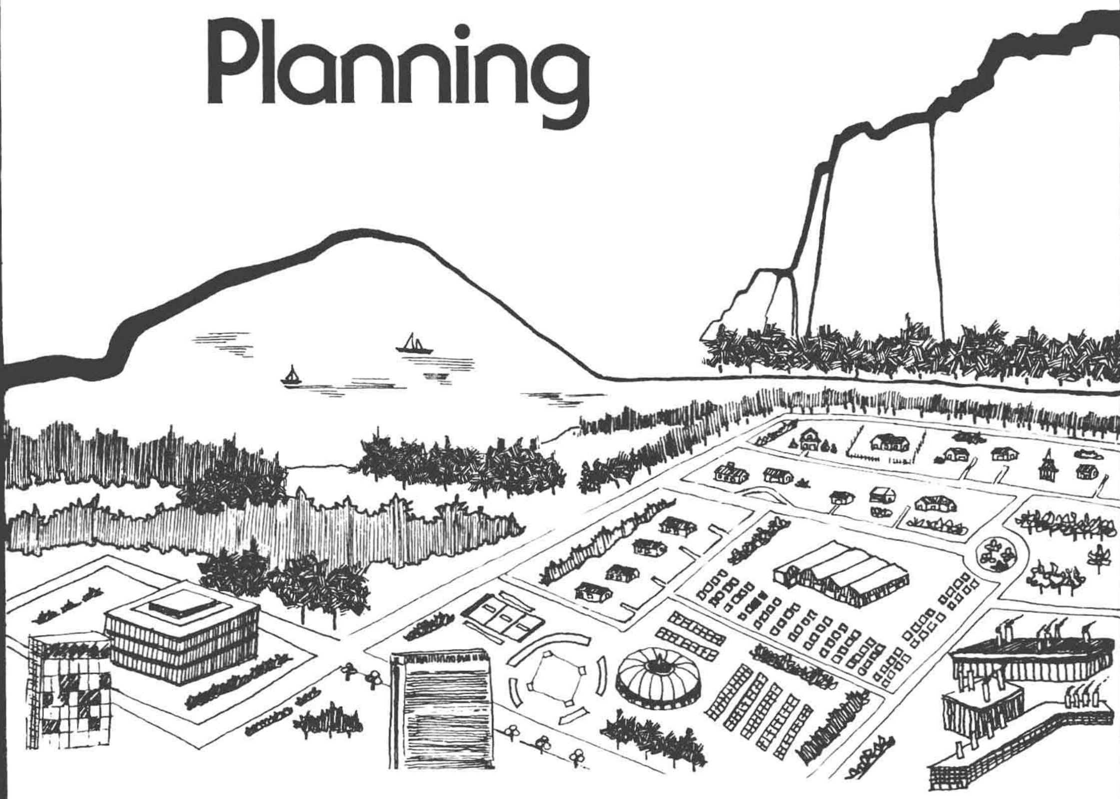

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The Earth
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Preface

THE initial outline and organization for *The Earth and Land Use Planning* arose from a course in environmental geology that one of us had taught at the University of California, Santa Cruz, for several years. It became clear that certain geologic and hydrologic processes were affecting society to a greater and greater degree and that these processes needed to be studied and understood. That understanding alone was inadequate quickly became apparent when we, as a geologist and an environmental planner, began working together in planning an environmental impact assessment within local government. Recognizing a landslide or a rapidly retreating sea cliff was one thing, but planning for land use in such areas and then implementing land use decisions was quite a different thing. Thus land use planning became a joint focus for the book as it relates to geologic and hydrologic considerations.

We believe this is a major departure from the "first-generation" texts published on "environmental geology" in recent years. These early books and collections of readings presented an instructional overview of the issues. We have tried to look deeper and see environmental geology as a focal point where both earth scientists and environmental planners can converge to solve important problems and make important decisions involving land usage and planning. Having two completely different backgrounds, earth science and environmental planning, but having converged in our work, we feel capable of presenting such a viewpoint.

Although many geologic hazards and environmental problems are regional in scope, such as volcanic activity on the West Coast, and strip mining in the Appalachians, every effort has been made to present environmental geology and planning in a broad geographic perspective. Examples are drawn not only from many places in the United States, but, where appropriate, from other regions of the world. We feel this should make the book particularly useful throughout this country. The land use and environmental planning orientation of the book streamlines its coverage to a degree and, therefore, the book avoids the comprehensive but unfocused coverage of issue-oriented texts. The basic processes and terminology appropriate to the subject are explained and covered in detail.

It did not seem appropriate to us, however, to offer an entire course in physical geology within this text. A glossary and appendices are included to define all necessary terms, and boxed essays are utilized to explain certain concepts and examples that amplify the text. For example, a boxed discussion of soils appears in chapter 7 within a discussion of erosion and sedimentation.

We feel the book is entirely self-contained and although some previous earth science would make it more meaningful to the reader, no such knowledge is required. Should the course instructor or the reader

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desire to cover material beyond the scope of this book we suggest the text be supplemented with one of the brief paperbacks on physical geology, energy, or more general environmental problems as is appropriate.

In addition to the book's land use planning orientation and its broad geographic coverage, we feel it is timely and useful for some other reasons.

The metric system is used throughout with English equivalents given where the authors felt appropriate. The coverage is up to date and includes very recent examples and information. A great deal of effort has been spent on illustrations to make the dynamic nature of the subject as visual and clear as possible. An entire chapter is included on basic concepts of land use planning and environmental impact assessment, both areas in which earth scientists are becoming more and more involved. We feel that the book should be useful as a text or reference for people in earth sciences, environmental sciences, geography, and environmental planning.

Acknowledgements

The authors are grateful to Donald O. Doehring, Colorado State University; Thomas Dunne, University of Washington; Donald Eschman, University of Michigan; Ira Furlong, Bridgewater State College; Ralph Gram, San Jose State University; Henry T. Hall, University of Minnesota; Robert M. Hordon, Rutgers University; and David M. Mickelson, University of Wisconsin, who reviewed the manuscript at various stages, and to Sheila Steinberg for her careful editing. We also want to give thanks to Venetia Bradfield, Cindy Daniels and Judith Bateman for their work in illustrating the book.

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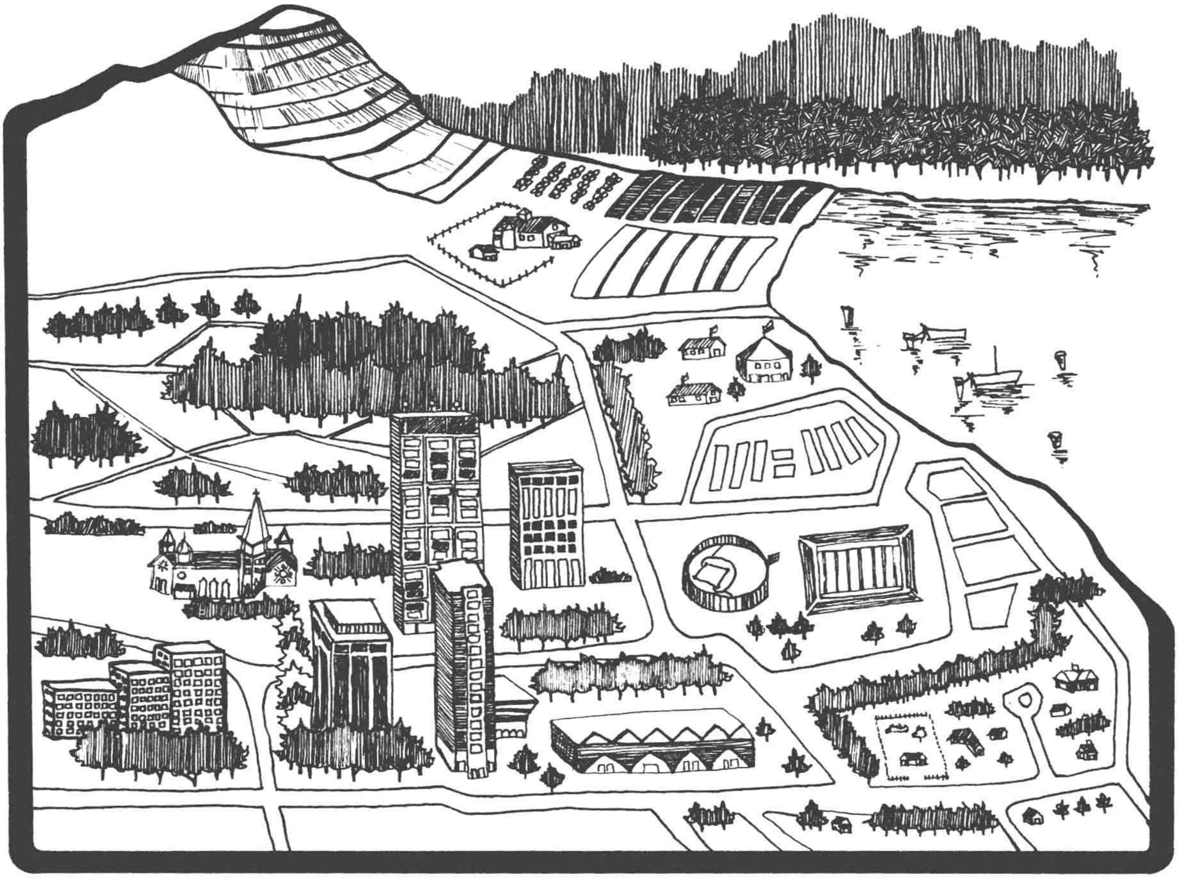

CHAPTER 1

Introduction

ALMOST every day newspapers carry stories on accounts of earthquakes, floods, hurricanes, or some other geological hazard or resource problem. It is difficult to visualize the human suffering, property damage, and economic disruption that result from inevitable natural disasters whose timing is completely uncertain. Despite this uncertainty, the magnitude of these events and their potential impact can be evaluated on the basis of past occurrences and existing knowledge (White and Haas, 1975).

The San Francisco Bay area of California will eventually be struck by a great earthquake, which may kill hundreds of people and injure thousands. Communications will be severed, utilities will be put out of commission, reservoirs may fail, hundreds of old buildings will collapse while many newer ones, including public buildings, will suffer major structural damage and become useless or unsafe.

A "dormant" volcano in the Cascades of the Pacific Northwest may erupt and cover hundreds of square kilometers with volcanic ash, ruining crops and contaminating water supplies. Mudflows generated by such an eruption could completely bury resort areas and entire towns in the valleys below.

A large hurricane will again strike the low-lying and heavily populated Miami area of the Florida coast. Storm tides, high winds and waves, and serious flooding will trap thousands of people, making evacuation impossible. Death and destruction will be even greater than during previous hurricanes because of increased population density and lack of adequate routes for evacuation.

Each of these events is possible, in fact very probable. The chapters that follow will deal with these hazards among others and bring out a number of points: prediction and forecasting will not in themselves prevent catastrophe; local awareness and responsibility are essential to prevent further encroachment into hazardous areas; and the

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failure to plan land use will only increase the potential for major loss and catastrophe.

We must understand that the land and water are both dynamic systems and limited resources which need to be considered in almost every action we take. The demands of more and more people and their concentration in urban areas require that we both safeguard these resources and give explicit consideration to natural hazards and processes in making land use decisions. In the past, land was treated strictly as a commodity — to be bought and sold in the real estate market. Natural obstacles such as hills or wetlands were either avoided where adjacent land was cheap or flattened and filled where land values were higher. Today regions can no longer be viewed as blank pieces of paper on which to write the story of irresponsible development; instead, the earth's surface everywhere has to be seen as a dynamic system, a combination of existing physical conditions that is constantly acted upon by natural processes, producing certain limitations or constraints on land use. To protect ourselves from geologic and hydrologic disasters, to guard against property damage and loss of life, and to conserve irreplaceable resources, the earth scientist and planner need to work together, each forging practical and constructive solutions from their knowledge and experience.

The successful interaction of human activity and nature requires the knowledge of the resources to be developed and conserved and also an awareness of hazards to be avoided or mitigated. Earth science information is essential to this integration and includes basic data from geology, soils, hydrology, and related scientific and engineering disciplines, along with the interpretation of those data.

Earth scientists are still working toward a basic understanding of many geological and hydrological processes acting at the earth's surface. Investigation and monitoring of the events that precede earthquakes or volcanic eruptions are examples of these research efforts. A clear understanding of a process that can be hazardous (excess runoff, leading to overbank flooding, for instance) or the recognition of an environmental constraint or limitation (such as the yield of a given groundwater reservoir or **aquifer**) is necessary before any rational planning or land use assessment can be made. The integration of geologic knowledge and the planning process is clearly exemplified by the land uses that might be appropriate in a 100-year floodplain (the area along a river that would be inundated by a flood likely to occur once every 100 years on the average). To calculate how much of a floodplain will be covered by water during the 100-year flood we need to analyze the existing discharge data for the stream in question. It is then necessary to make some calculations utilizing this data that can then be applied to accurate topographic maps of the floodplain. The ultimate goal in this case is the zoning or delineation of risk zones in the floodplain, which would then establish controls or limitations on all land usage or development.

What happens if we choose to disregard or ignore these natural hazards and limitations and simply let everyone use the land as they wish? What is the danger or cost of failing to respond to the natural limitations of the physical environment? When there were fewer people on the earth and they were more widely dispersed, the problems were relatively insignificant. Now, however, depending upon the severity of the hazard and its recurrence interval, costs in terms of property damage and human life can be extremely high. The earthquake of February 4, 1976, in Guatemala, for example, resulted in the death of about 20,000 persons. A recent study by the California Division of Mines and Geology (Bulletin 198, 1973) entitled "The Nature, Magnitude, and Cost of Geologic Hazards in California and Recommendations for Their Mitigation" is a good analysis of the problem of hazard assessment. Given a continuation of present practices, it is estimated that property damage and the dollar equivalent of loss of life directly attributable to geologic processes and conditions, and the loss of mineral resources due to urbanization, will amount to more than $55 billion in California alone between 1970 and the year 2000 (see figure 1.1). Average annual flood losses in the United States by the year 2000 are estimated to be about $3.5 billion.

To reduce or minimize these losses we can work toward extending the application of existing techniques and knowledge or to-

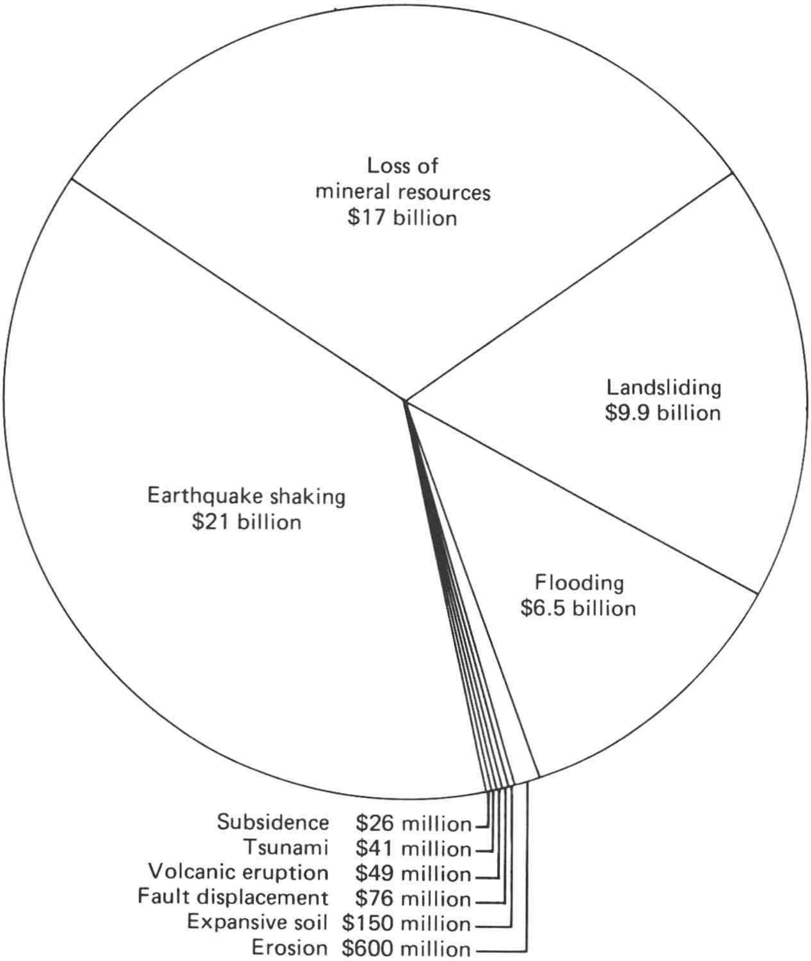

Figure 1.1. *Geologic Hazards in California to the Year 2000: A $55 Billion Problem.* REDRAWN FROM: *J. T. Alfors, J. E. Burnett, and T. E. Gay,* Urban Geology Master Plan for California: The Nature, Magnitude and Costs of Geologic Hazards in California and Recommendations for Their Mitigation *(California Div. of Mines and Geology Bulletin 198, 1973).*

ward improving our hazard reduction capabilities. Both seem logical and necessary. Losses from earthquake shaking, for example, can and should be reduced through a combined effort involving geologic and seismologic research, engineering practices, building codes, urban planning and zoning, fiscal and taxation policy, and preparedness planning. Priority efforts, such as strengthening older hazardous buildings, demolishing them, or reducing their use, need to be applied to reduce the loss of life. Adequate implementation of measures that can reduce losses is dependent upon the level of enforcement provided by local government. If all presently feasible loss reduction measures were applied and all current practices were upgraded to the current state of the art throughout California alone, an estimated $38 billion reduction of the projected $55 billion losses in that state could be achieved. The total costs of applying the loss reduction measures are estimated to be about $6 billion (*see* figure 1.2). In many areas legislation is requiring local governments to recognize and come to grips with these or other hazard reduction problems. The need exists for earth scientists and planners to work together to identify problem areas and then to plan for appropriate future land uses.

For any earth scientist who has been concerned with the problems of geologic hazards and land use, or for any environmental planner who has attempted to utilize geologic information in his or her work, there are still some obvious communication and information gaps. Geologists, in the minds of most planners, lack an understanding of the planning process and how their work might best fit into it. Geologists also need to learn how to communicate the results of their work to people other than their own colleagues. In the minds of many geologists, the common desire of planners is for a brief report unsupported by technically sound data. Geology in the past has only been very incidental to planning. All this is beginning to change, however. Many earth scientists are now very much involved in the applied aspects of geology and are keenly interested in putting existing data into a usable form and then into the hands of planners who will use it. New geologic maps depicting landslide distribution, slope stability, soil thickness, and depth to water table are being generated and used. The publicized failures and disasters where urbanization or development has encroached on unstable land, combined with the availability and demand for geologic data, have begun to bring the earth sciences into the planning process. Geology and hydrology are as essential to planning as any other components or inputs, and planners have to realize this and become familiar with these disciplines.

Within this book we have discussed geologic hazards in the first five chapters, including descriptions of the basic physical processes, how, why, and where they occur, how to recognize hazardous areas, and how hazards can be mitigated or avoided through the planning process. The latter sections of the book cover waste treatment and disposal, geologic and hydrologic resources, and planning environmental impact and land use control. These chapters should acquaint environmental planners with the physical processes and limitations of the earth and inform scientists how geologic and hydrologic information fit into the planning process.

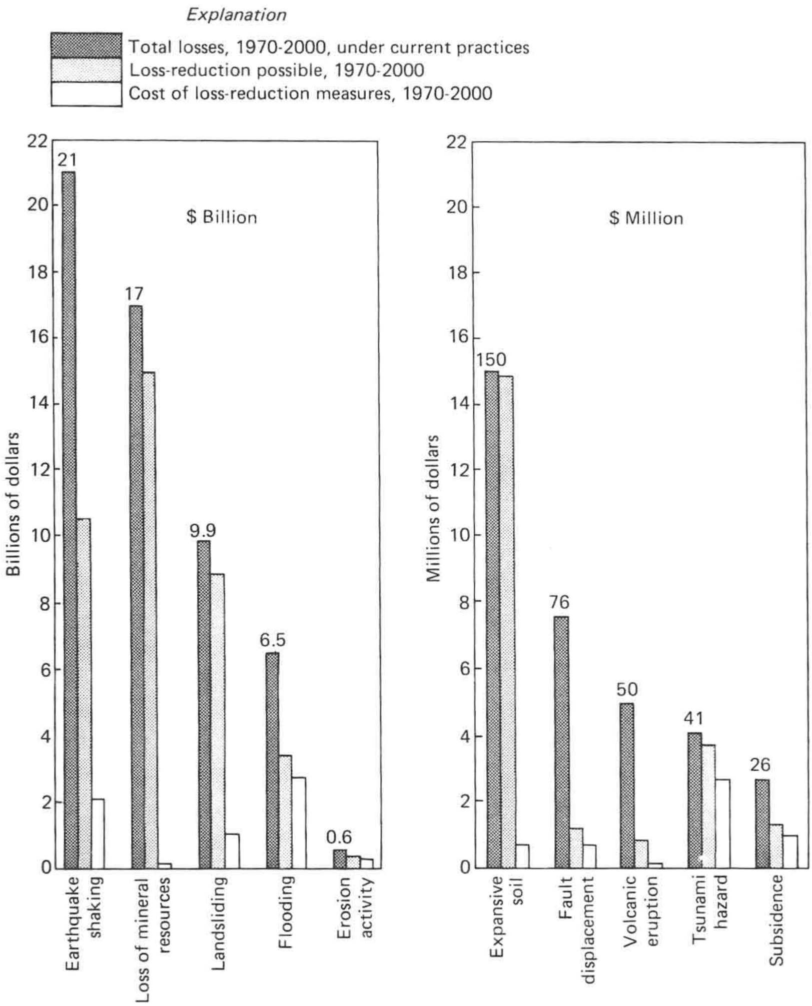

Figure 1.2. *Estimated Total Losses Due to Each of Ten Geologic Problems in California for the Period 1970 to 2000.* REDRAWN FROM: *J. T. Alfors, J. E. Burnett, and T. E. Gay,* Urban Geology Master Plan for California: The Nature, Magnitude and Costs of Geologic Hazards in California and Recommendations for Their Mitigation *(California Div. of Mines and Geology Bulletin 198, 1973).*

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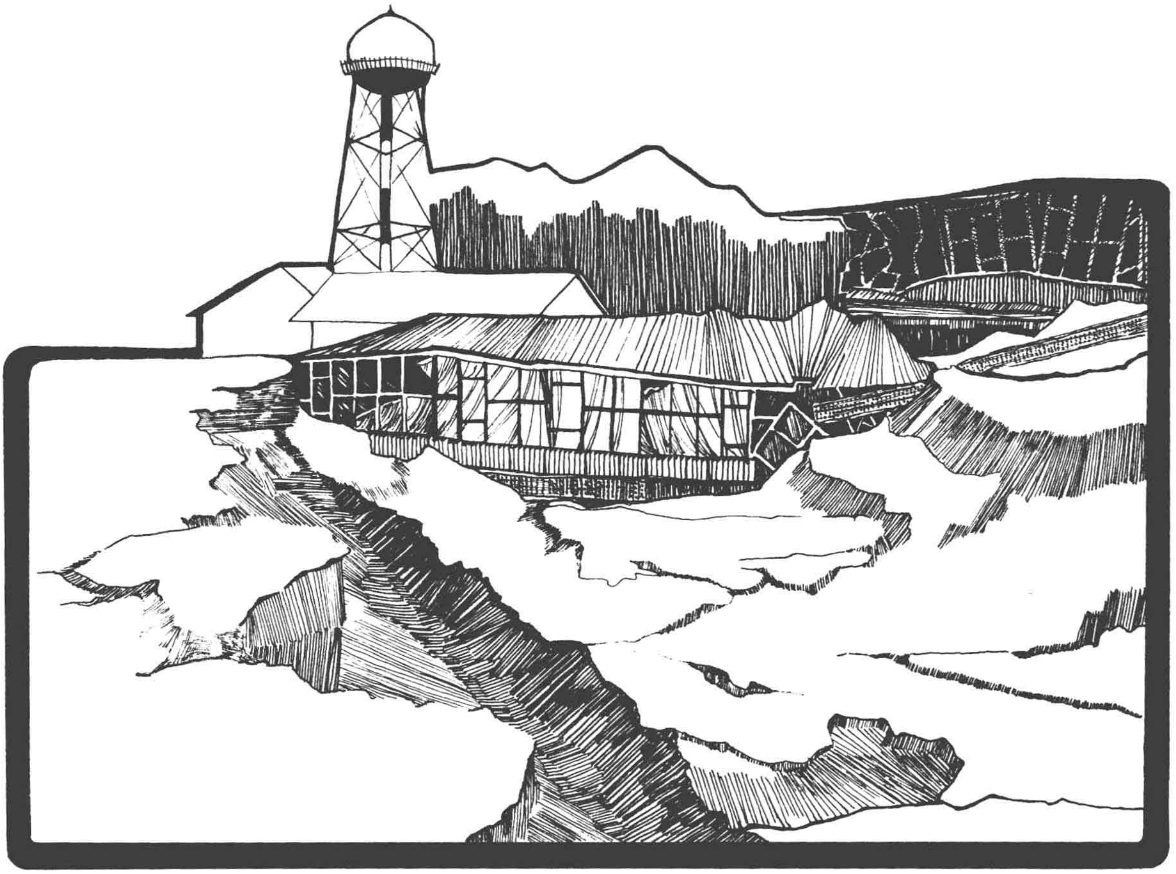

CHAPTER 2

Earthquakes and Faulting

Contents

INTRODUCTION

THE earth is continually evolving and undergoing change. From our viewpoint at the surface of the earth, we observe and are affected by both surface processes and the external expression of activity occurring deep within the earth. This activity may be very slow and take place over millions of years, as in the case of mountain building. It may also occur very quickly without warning, as in the case of a major earthquake. Much of the large scale earth movement of concern to us is concentrated along faults, or breaks in the earth's crust. When movement occurs suddenly along a fault, energy is released in the form of an earthquake.

Major earthquakes in the past have destroyed everything from primitive villages to modern cities. Since 1900 alone, there have been twenty-six major earthquakes throughout the world that have resulted in serious loss of life (see table 2.1). Most people in the United States tend to think of the 1906 San Francisco earthquake, which resulted in the death of about 700 people, as a major disaster. Although property loss was very high due to the fires that followed the shock, the

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