# Geology, Cities, and Surface Movement

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From the earliest times, geological factors have affected man's life and works in a variety of ways. The results of earthquakes, landslides, and floods are dramatic and increasingly prevalent negative aspects of geology. The availability of construction and industrial materials, of energy sources, of pure water, and of conditions conducive to clean air are equally important geological factors that may enhance or limit urban development. All of these factors and limitations can be understood and taken into account in the planning of cities and transportation networks if their importance is appreciated and acted upon. Indeed, they should play a vital part in future area-wide transportation planning and development.

Conceptual blueprints are needed for all urban regions where geological hazards and material limitations are recognized. Hazardous construction areas can fill the need for recreation and open spaces. Areas underlain by construction or industrial materials can be scheduled for a sequence of "best uses." New cities, needed to accommodate expanding populations, could be nucleated around new "urban grant universities" to provide for the increased enrollments expected in the colleges and universities by 1977. In moving to meet the existing urban crisis, we must be wary of an outlook so restricted as to foment an even greater megapolitan crisis for the future.

•THROUGHOUT history and in all parts of the world, the routes of travel, the dwelling places, and the affairs of man have been influenced by geology. The effects are often obscure, but they are always important, and they are sometimes profoundly important. With our fast-growing urban populations and the growing transportation networks that are needed to serve them, the critical and complex interactions among geology, cities, and transportation networks must not remain obscure.

The waterways, valleys, and mountain passes through which the trade goods of ancient peoples passed are reflections of geologic processes and structure. The very caves in which our early ancestors dwelt were geologic features, and the pigments that still glow so richly on their walls at Altamira and elsewhere were produced with mineral pigments that had been transported along local trade routes. Larger aggregations of people settled where trade routes intersected, or at the sites of mineral resources or water power. As buildings were built and cities developed, they reflected the nature of the prevalent local building materials and mineral resources. The need for people and goods to move into and out of cities and between cities required transportation networks, and they too took much of their character and durability from subsurface conditions and available construction materials.

Whole civilizations have risen and fallen for essentially geological reasons. Lovering (17), for example, points out that the defeat of Xerxes' Persian horde by a handful of Spartans at Thermopylae in 400 B.C. was due not only to the valor and discipline of

Paper sponsored by Department of Economics, Finance and Administration; Department of Urban Transportation Planning; and Department of Soils, Geology and Foundations and presented at the 48th Annual Meeting.

the Spartans, but also to their use of British bronze against the stone-age weapons employed by their adversaries. And the existence of British bronze was closely related to the fortuitous geological juxtaposition of tin and copper deposits in Cornwall.

The flowering of Athens was just as much a function of the richness of the silver mines of Laurium as of the remarkable genius to which these gave the leisure to flower. Over the road that connected Laurium in southern Attica to Athens, 25 miles to the north, there flowed during some three centuries beginning about 650 B.C. a bonanza of silver having a purchasing power in current terms of around $65 billion. This is the equivalent of about $1,000 of new currency per year per person for the entire population of Athens, averaged over the centuries of high productivity (7). A rich new ore-body found at Laurium in 483 or 482 B.C. was used to finance the building of the fleet that defeated the Persians at Salamis in 480 B.C., turning the tide of human history! The building stones of Athens and the marble of her temples and statuary—all geological resources—were quarried, hauled, and worked by virtue of this same silver. When Laurium declined, Athens also declined. Then new finds of silver and gold in Macedonia financed the conquests of Philip and Alexander. The flaw in both of these economies, as it still is in some, was to rely on too narrow a base of nonrenewable resources.

Rome developed a fabulous transportation system and grew rich on a variety of imported products—Cornish copper and tin, Spanish silver and lead, and Near-Eastern gold. Local building materials were abundantly available, easily fabricated, and well-suited to the urban construction of Roman times. A great civilization evolved and then disintegrated when many of her most creative citizens were selectively killed off without issue by chronic lead poisoning from lead-lined cooking vessels and wine cups and the use of lead oxide as a preservative (12, 17). A resource misused had become an insidious and lethal pollutant, not unlike the elements of modern urban smog.

The subsequent growth of cities and industrial civilization, no matter how the GNP is figured, has been clearly dependent on availability of mineral raw materials, mineral fuels or other sources of power, suitable construction materials and foundation characteristics, and a relatively efficient transportation network. Examples could be multiplied, but the lesson is clear: geology is a key factor in comprehensive area-wide transportation planning and urban development.

Rather than touch briefly on too many aspects of this relation, however, I will consider here only some aspects of geology as it bears on modern urban development and the related highway network. In particular, I will refer to southern California, where the geological aspects of highway and urban engineering are especially critical and are receiving increasing if belated and still-inadequate attention. This report primarily concerns the features that bear on highway and urban engineering, rather than the raw materials of industry whose availability must also be considered in city planning, but which are more negotiable assets.

Geology affects urban development and the related movement of goods and persons in many ways—often subtle, sometimes dramatic. It affects them first in its influence on the very locations of cities and routes of surface transport. It affects them in terms of the relative availability of construction materials and the continuing access to metal, energy, and water resources. It affects them as regards topography, climate, and soil as they reflect geological conditions. And it affects them in terms of foundation characteristics—i.e., susceptibility to earthquake shock, stability under load, slope stability, and ease or difficulty of construction.

## NATURAL HAZARD

Consider the problem of natural hazard. No part of the earth is free from the threat of natural hazard, although hazard is rarely perceived in the public mind in advance of catastrophe. Moreover, the events that appear as catastrophes when they affect man or his works are all attributable to perfectly natural and recurrent or enduring processes that can be understood, foreseen, and in large degree managed or avoided.

Aside from the vagaries of weather or viral epidemic, the commonest and most dramatic hazards are geological. Earthquakes, landslides, subsidence, foundation failures, and floods are major causes of property damage and loss of life. In 1958, landslides were already taking an annual toll of hundreds of millions of dollars worth of property damage in the United States alone (25). Although it is unduly optimistic to think of prediction and control in the sense of identifying the precise time and place of onset, or of preventing the works of nature, various parts of the earth can be classified as to likelihood and kind of hazard. The times at which that hazard is likely to be greater than others can be determined, and understanding the processes involved can be learned. Based on such knowledge and understanding, best-use plans for the various parts of the earth's surface, and techniques of environmental engineering that will operate in harmony with nature instead of unbalancing established equilibria or confronting her with ineffectual or destructive displays of brute force can be developed.

Although the hazards are natural, they are only hazards where man is present. However, many catastrophes are provoked by the actions of man, and damage is in direct proportion to the concentrations of man and his works at the scene of action. The hotly pursued but meretricious goal of exponential growth in increasing the numbers and concentrations of people, the rate of industrial development, and the prevalence of highways and other public works have also increased exponentially the exposure to hazard and therefore the incidence of property damage and other effects of perceived catastrophe.

The world's largest and best-known cities originated where resources were located, or along coasts, waterways, or natural transportation routes to which it was easy to fetch resources. Changes in technology, resource concepts, and transportation have made possible new cities in new locations, but the old ones continue to grow. They grow most dramatically where the landscape is most dramatic, along coasts or waterways, and where the climate is mild and equable. Because such dramatic landscapes, waterways, and coasts are the natural sites of geological instability and because the operations of man often work against natural steady states, it is not surprising that the growth of populations and cities is accompanied by increasing property damage (if not by increasing loss of life), particularly in view of the inadequate advance attention normally given to natural differences in slope stability, potential movement along faults, and exposure to other natural hazards.

Even in the peaceful and relatively thinly settled farmland of the limestone valleys in southeastern Pennsylvania, cavern collapse and the formation of sinkholes is not infrequent, occasionally causing damage to property. Such failure is more likely to attract attention when it happens under large and expensive equipment, as it did to bombers on western Pacific airfields during World War II, or where it involves damage to residential areas as in some coal-field and oil-pool subsidence.

As in many other aspects of growth, however, those on the Pacific Coast lay valid claim to even more spectacular events than simple direct subsidence from sinkhole formation or collapsing soils, spring thaws, overbank streams, or the piddling landslides and rock falls of more easterly areas. One of the reasons for this is that California combines an abundance of active zones of crustal movement, or faults, with many steep slopes and often unstable surface materials that may fail when overloaded or overwetted, or when the faults move.

The effects of geological hazards are particularly impressive in the Los Angeles region. In the spring of 1928, the soft conglomerate beneath the St. Francis Dam in San Francisquito Canyon (Ventura County) gave way, causing the death of 426 people and large property damage (23). As recently as 1963, failure of the Baldwin Hills Reservoir cost $15 million in damages and took five lives. The La Canada flood of 1938 was a devastating event for the people who lived and died in its path, on what to them must have looked like a safe, dry, and relatively gentle hillslope.

Areas of perceptibility and the prospects of catastrophe were greatly increased by the spurt of growth that accompanied and followed World War II and the engineering achievements that spread a growing population up the hitherto relatively inaccessible slopes. Highways that cut into the toes of landslides, construction that overloaded the same or other landslides, and lubrication from the gardener's hose conspired with nature to increase or regenerate natural slope instability. Growth of paved areas increased the rate of runoff. The climax came with the heavy winter rains of 1951-1952. Landslides, slumps, and debris flows on the modified hillsides combined with flash floods in the normally dry valleys to produce $7.5 million worth of damage in Los Angeles.

Then in 1956, in perfectly fine summer weather, about 400 acres of a long-known landslide that had been developed as a residential area despite its delineation on a map published ten years previously (27) began to ooze downslope at Portuguese Bend in the Palos Verdes Hills and has continued to move, taking the access roads and a commuter's highway with it. The resulting damage to the expensive residences on its surface has been estimated at over $10 million, and resulted in a court judgment against the County of Los Angeles in the amount of $5,360,000 (22) for the alleged overloading of the slide by highway fill along its upper margin. The Portuguese Bend slide, moveover, is a relatively small slide. Some of the numerous landslide areas shown on geologic maps of the Coast Ranges of California attain lengths as great as 10 miles (22). The largest landslide known (at Saidmaneh, Iran) is estimated to have had a volume of over 21 billion cubic yards (22). Imagine what something like that would do to Los Angeles, San Francisco, or other landslide-prone cities!

Because 60 percent of the Los Angeles area consists of hillsides, and because these are now the least populated, the most hazard-prone, and yet the most rapidly growing parts of Los Angeles, it is obvious what is in store for many of the two million new people that Los Angeles City and County officials hope to welcome to the area in the next 25 years.* Then there is San Francisco, which is spreading along the San Andreas fault and onto fill above the unstable mud-flats around lower San Francisco Bay. And of course, there are high-rise buildings along faults or on foundations of dubious stability in both Los Angeles and San Francisco. Anchorage, Alaska, has existing construction and development plans that promise to overload the superb sliding surface of the Bootlegger Cove clay that lies at shallow depths beneath most of the city (8), and which failed so dramatically in response to the earthquake shock of March 27, 1964. Numerous other examples are given by Morton and Streitz (22).

Even seemingly peaceful areas of gentle terrain have been affected by devastating earth movements within historic time. The 1811 earthquake at New Madrid, Missouri, triggered sliding and subsidence in a 5,000-square mile area, including nearly continuous sliding for some 40 miles along the Chickasaw Bluffs. The earthquake that shook the eastern states in November 1968 was probably 2½ orders of magnitude less severe, but it proves that the region is not seismically inactive. Loss of life and property damage can occur in the east also, as it did in the devastating earthquake at Charleston, South Carolina, in 1886 (9).

Flood damage, moreover, episodically destroys homes, highways, and businesses in places like the Connecticut, Minnesota, and Mississippi River Valleys, despite gargantuan efforts at control. If we were to look at the United States or the world as a whole, the list of natural catastrophes would be horrendous. Unfortunately, however, only limited support is available for the studies that can lead to the understanding that must precede any rational hope of prediction or control.

## OTHER GEOLOGICAL FACTORS

Geological factors other than natural hazard are an appropriate part of this subject, but water supply, air and water pollution, and most of the rest are either adequately in the public awareness or of only remote interest here. Problems of water in urban planning have been summarized by Leopold (16).

However, construction materials cannot be omitted from this discussion. Every home, public building, industrial installation, reservoir, street, and highway consumes, and many of them cover up, resources that are needed in large volume, and whose cost increases with the distance they must be transported. In California, stone, sand, and gravel have an aggregate annual value second only to oil and 100 times greater than gold—accounting for about two-fifths of the current annual mineral production in the state (about $500 million). Most construction materials are valuable only when they

*Shortly after this was written, earth movement and floods from the storms of January 17-19 and 24-25, 1969, claimed 91 lives and caused $60 million worth of property damage in southern California.

are nearby, and if there are none nearby, costs of construction escalate. For instance, a recent study by the Intercounty Regional Planning Commission for the Denver region showed that, of the 925 million tons of sand and gravel originally available there, about half had been used and half of that left had been built upon. Only 244 million tons remain, which is about 24 years' supply at current rates of use (11), and much less where growth is exponential.

Between now and the end of the century, while the population of the United States increases from 200 million to an estimated 320 million, additional housing, roads, and urban, educational, and industrial facilities equivalent to all of those already in existence must be built. This will require enormous volumes of stone, sand, gravel, clay, etc., the nearby sources of which are at many places being rapidly covered up by construction.

Because it is obviously impracticable to tear down residential, industrial, or business districts to get at materials of low bulk cost needed in large volume, or to forbid construction on land whose value for building has generated strong pressures for development, it would be prudent to know before such pressures occur where the building materials are and to classify appropriate lands as construction materials reserves. These areas should not be used for purposes other than quarrying or recreation until the needed materials have been removed to safely exploitable depths and the surface restored for other uses. A similar sequence of uses or other special handling may be prescribed for subsurface resources where their removal from beneath "developed" land would likely lead to surface hazards or undue legal complications.

## PLANNING FOR THE FUTURE

Problems such as these cannot be ignored indefinitely. Man may be oblivious to the needs of distant posterity or to hazard, but he does respond to the wants of his children and to disaster. Repeated disasters and imminent wants may even provoke consideration of causes, remedies, and evasive action. What is being done and what should be done about the fact that we can no more insulate ourselves from natural forces and configurations than we can forego the need of living somewhere and moving about on the earth's surface?

Most important is that the people who know about the natural hazards and limitations and the people who are planning cities, airports, reservoirs, aqueducts, and surface transportation for the future shall communicate with one another. Here, then are some of the things that need to be done generally and that the planners ought to be trying harder to bring about.

Although New York City was the first large city in the United States to develop and utilize engineering geology on anything like an adequate scale, and although several other cities are showing increasing awareness of their geological problems, it is Los Angeles that best visualizes the direction in which we must move in the use of geology in urban planning and highway design. Geologists of the U.S. Geological Survey and the California Division of Mines and Geology have, of course, been active in the area for years. Yet, until recently, little attention was paid to their work by city planners, and there were no geologic ordinances and no geologists on the city payroll. Then came the disastrous floods, slides, and foundation failures of 1951-52—affecting a large number of individual home owners and commuters. Response to the widely distributed \$7.5 million tab was rapid, and the \$5,360,000 judgment against the County for damages in the case of Portuguese Bend brought the problem home to all taxpayers in a concrete manner. As a result, about 50 geologists were dealing with urban problems in the Los Angeles region by 1953, and this number had increased to about 150 by 1963. It is perhaps 200 by now, although many of them work at the job only intermittently.

Los Angeles County has about 10 geologists working for its Flood Control District and about 13 with the County Engineer's Department. The City of Los Angeles, which hired its first geologist for urban planning in 1958, now employs about five geologists in the Dams and Foundations Section of its Water and Power Department and about six in its Bureau of Standards. The Metropolitan Water District of Southern California now has about 12 geologists, but explosively growing Orange County limps along with one.

The rest of the estimated 200 geologists are federal or state employees, consultants with private engineering firms, independents, or university professors doing part-time work.

Geologic mapping for urban planning is being carried out in a number of developing areas in southern California at scales that show an inch on the map as equivalent to 400 to 2,000 feet on the ground (3). These now include one study by the Los Angeles City Bureau of Standards, several by the Metropolitan Water District, 11 by the California Division of Mines and Geology, and three by the U.S. Geological Survey. The services of the state and federal geologists are normally available to counties and cities for planning purposes on request, and their reports are inexpensive public documents available from the U.S. Government Printing Office or state agencies.

The U.S. Geological Survey, meanwhile, has instituted a program of regional studies throughout the nation that is specifically designed for urban planning purposes. Three of these studies had been completed and published and 11 more were in progress in 1964 (20). State geological survey studies for urban planning have also been instituted or completed at several places, such as Bloomington, Indiana, the Chicago area, and Minneapolis-Saint Paul. In addition to showing the locations of faults along which earthquakes may occur and classifying the surface and subsurface rocks according to their engineering properties and suitability for construction materials, an important product of such analyses is the slope or subsurface stability map. Cleveland and Blanc (4) have illustrated the relation between geologic and slope stability maps at San Clemente, California, and Leighton (14) illustrated a damaging small landslide that occurred in one of the coastal bluffs mapped as an unstable site after mapping had been completed. Other examples where foundation instability was predicted on maps made available well in advance of damaging failure include the Palos Verdes Hills in coastal Los Angeles (27) and the Anchorage lowland in Alaska (21). Unfortunately, the existence of such information has rarely come to the attention of city planners and private builders in advance of the damaging events.

Is enough research in urban geology and environmental engineering being conductec The person trapped in a landslide or flood, or made homeless by earthquake, foundation failure, or rampaging waters will always be hard to convince that enough has been done no matter how much may have been done in the past. It is equally difficult, of course, to persuade that some person, in advance of damage to himself, that he should support research, refrain from building or buying on unstable ground, or agree to the establishment of codes that will increase construction costs. It is even difficult to introduce a geological dimension to highway engineering and public construction.

If, however, what has already happened is merely a prelude to greater and more widespread hazard to life and property where present patterns of urban growth and public works are continued, what can and should be done?

To begin with, all existing and contemplated cities and highway networks should have development plans and limits based on careful and detailed studies of all natural forces and components—geologic structure, engineering properties of rocks and soils, slope stability, construction materials, characteristics of ground and surface waters and their susceptibility to contamination, mineral resources and the results of their exploitation, and climatology, including rainfall patterns and susceptibility to stagnation and pollution of the atmosphere. All cities and highway departments should have staffs of geologists and other environmental scientists capable of collecting and interpreting the data. This could be done at a small fraction of the annual bill for damages from avoidable causes.

Landslides and faults are among the sources of difficulty most easily recognized, yet they continue to exact staggering tolls. The faults along which many major earthquakes have occurred are well-known and often conspicuous geologic features, such as the San Andreas fault. The landslide that killed 18 campers as a result of the 1959 Hebgen Lake earthquake in south central Montana was detached from a mountain slope that showed conspicuous evidence of previous avalanches and rockfalls. The present expansion of the San Francisco metropolitan area along the scenic San Andreas rift zone and on the bayside flats that shook like jelly from the surface waves of the 1906 earthquake holds sure prospect of future disaster. Although it cannot be said just when the next earthquake will come or exactly how bad it will be, there is a good chance that its consequences will greatly overshadow the toll of 600 dead and $400 million worth of property damage attributable to the 1906 earthquake.

Such places, as well as other areas of known natural hazard, should be reserved for the greenbelts, parks, golf courses, and nature preserves that will be so essential to the sanity of our future urbanite and the restoration of his jaded perspective. Where use for public works is deemed necessary, alternative sites should be evaluated on a combination of engineering feasibility, cost, and geologic conditions. Where no alternative is found, construction should be accompanied by all of the engineering precautions required to minimize the hazards that can never be eliminated.

Ground underlain by construction or industrial materials needed for future development should be zoned so as to be used first for that purpose, after which the surface can become recreational (lakes, parks, ski areas, golf courses), residential, or industrial land. Suitable openings underground can also be used for a variety of purposes.

Above all, new cities are needed to take care of the urban population growth that is inevitable, over the near term at least, and which cannot reasonably take place within existing cities without severely aggravating the already serious urban crisis and overloading the practicable highway networks. These new cities need not be bound by the restrictions that caused old ones to be located along traditional surface trade routes or near bulky resources. The only bulky resources that are absolutely essential to a modern city are construction materials, clean air, and pure water. In a transistorized society, fueled by nuclear energy, much profitable light industry can be based on relatively small quantities of raw materials, easily transportable to the kinds of places where people might choose to live and work.

Human creativity and the enhancement of natural values through processing are the greatest resources with which we deal—although, of course, there must be something to fabricate. There is no need to allocate unwilling residents to new cities. By using imagination, technological capability, and ecological and sociological wisdom, it is possible to create new urban modes that will serve as magnets for people, and transport facilities that will move them and their goods in and out with ease. All existing cities have developed at places where once there were no men. Why shrink from the thought of deliberately creating new cities where there are now few men, especially if such places are delightful places otherwise?

Think of a city of about a million as a size that can present all conceivable amenities of urban life without intolerable growth of the accompanying drawbacks. At least 120 of these new cities should be on the drawing boards right now (for the United States alone) to accommodate the population pressures of the next 30 years without exacerbating the problems of existing cities. More would be better. The stimulation of such development and the selection of sites for these future urban centers and the surrounding suburban settlements could well be fostered jointly by the Departments of Housing and Urban Development, Interior, and Health, Education and Welfare. Site selection should involve a considered balance of natural conditions, including geology; the possible interest of private industry and government agencies in establishing new ventures there; the availability of land and reasonable cost; and the sociology of the people who might live and work at such places.

It has already been shown that, given the choice, 80 percent of the people inhabiting present central cities would rather live in less congested places (Gallup Report, May 5, 1968). Since it could hardly cost much more to move such people to newer smaller towns than to relocate them on renovated space that is now urban, it is hard to see why some of them should not be relocated, thereby reducing the stresses of crowding both on those moved and on those who stay behind, as well as diminishing the strain on local construction materials. In considering how to meet the existing urban crisis, planners must be wary of an outlook so restricted as to generate an even greater megapolitan crisis for the future.

It is suggested elsewhere (5, 6) that many of the needed new cities might be nucleated around new "urban grant universities," which would seek to integrate public and private interest in the preservation and enhancement of environmental quality through schools of environmental science and public programs. In case this seems impracticable, remember that 120 new universities with enrollments of 25,000 students each would just take care of the 3 million additional students that the Carnegie Commission on Higher Education (2, p. 4) expects will be added to the 6 million students now attending colleges and universities by 1976-77.

Many public lands in this country are little used, and their use could be increased without inacceptable hazard to the environment under appropriate controls. Sizable grants of property at the margins of suitable public land could be made for the establishment of urban grant universities. The universities can either develop themselves or they can lease the land to developing high-technology industries with low material requirements, low bulk yields, and low capacity for pollution. The new cities and their road nets can grow around such nuclei and be marginal to the public lands, which should remain open under rigorous control for limited recreational use. Within such projected urban regions, land classification and, if warranted, a succession of uses would be scheduled according to natural properties and best use or best succession of uses. Areas of potential hazard would be set aside for parks, greenbelts, golf courses, and smaller nature reserves. New styles in construction of buildings, public works, and surface transportation could be experimented with and, where successful, could be applied to the continuing improvement of older urban centers.

These are ideals that some believe can be realized only in a completely planned economy. However, the essential benefits of planning must be made to happen within a free but responsible economy.

## REFERENCES


1. Allen, C. R., Housner, G. W., and others. Earthquake and Geologic Hazards in California. Report to the Resources Agency (State of California) by The Geologic Hazards Advisory Committees for Program and Organization. April 26, 1967, 18 pp.
2. Carnegie Commission on Higher Education (Clark Kerr et al). Quality and Equality—New Levels of Federal Responsibility for Higher Education. McGraw-Hill N.Y., 1968.
3. Cleveland, G. B. Current Regional Geologic Studies in Southern California. In R. Lung and R. Proctor, editors, Ref. 18, p. 214-215.
4. Cleveland, G. B. Why Landslides? Calif. Div. Mines and Geology, Mineral Information Service, Vol. 20, No. 9, p. 115-117, 120, 1967.
5. Cloud, P. E., Jr. Government and the Climate for Science. In Climate for Science. American Science Teachers Assoc. (in press).
6. Cloud, P. E., Jr., and McKelvey, V. E. Environmental Sciences and National Goals. In Applied Science and Technological Progress. Report to the Committee on Science and Astronautics, U.S. House of Representatives, by the National Academy of Sciences. U.S. Govt. Printing Office, 1967, p. 229-254.
7. De Golyer, E. The Mines of Laurium. Trinity College Commencement Address, Hartford, Conn., 1947.
8. Dobrovolny, E., and Schmoll, H. R. Geology as Applied to Urban Planning—An Example From the Greater Anchorage Area Borough, Alaska. In Q. Záruba, editor, Ref. 29, p. 39-56.
9. Dutton, C. E. The Charleston Earthquake of August 31, 1886. U.S. Geol. Survey, Ann. Rept. No. 9, p. 203-528, 1889.
10. Eckel, E. B. (editor). Landslides and Engineering Practice. HRB Spec. Rept. 29, 1958, 232 pp.
11. Flawn, P. T. Geology and Urban Development. In R. Lung and R. Proctor, editors, Ref. 18, p. 209-213.
12. Gilfillian, S. C. Lead Poisoning and the Fall of Rome. Jour. of Occupational Medicine, Vol. 7, p. 53-60, 1965.
13. Le Grand, H. E. Urban Geology and Waste Disposal. Geotimes, Vol. 13, No. 6, p. 23, 1968.
14. Leighton, F. B. Landslides and Hillside Development. In R. Lung and R. Proctor, editors, Ref. 18, p. 149-193.

15. Leighton, F. B. Preliminary Map Showing Landslide Locations in a Portion of Southern California. In R. Lung and R. Proctor, editors, Ref. 18, p. 194-200.
16. Leopold, L. B. Hydrology for Urban Land Planning—A Guidebook on the Hydrologic Effects of Urban Land Use. U.S. Geol. Survey, Circ. 554, 1968, 18 pp.
17. Lovering, T. S. Some Cultural Contributions of the Geological Arts and Sciences. New Mexico Acad. Sci. Bull., Vol. 7, No. 1, 1966.
18. Lung, R., and Proctor, R. (editors). Engineering Geology in Southern California. Assn. of Eng. Geologists, Los Angeles Sec., Spec. Pub., 1966, 389 pp.
19. McCauley, M. L. Engineering Geology Related to Highways and Freeways. In R. Lung and R. Proctor, editors, Ref. 18, p. 116-121.
20. McGill, J. T. Growing Importance of Urban Geology. U.S. Geol. Survey, Circ. 487, 1964, 4 pp.
21. Miller, R. D., and Dobrovolny, E. Surficial Geology of Anchorage and Vicinity, Alaska. U.S. Geol. Survey, Bull. 1093, 1959, 128 pp.
22. Morton, D. M., and Streitz, R. Landslides. Calif. Div. Mines and Geology, Mineral Info. Serv., Vol. 20, No. 10, p. 123-129, No. 11, p. 135-140, 1967.
23. Pestrong, Raymond. The Role of the Urban Geologist in City Planning. Calif. Div. Mines and Geology, Mineral Info. Serv., Vol. 21, No. 10, p. 151-152, 1968.
24. Radbruch, D. H. Engineering Geology in Urban Planning and Construction in the United States. In Q. Záruba, editor, Ref. 29, p. 105-112.
25. Smith, Rockwell. Economic and Legal Aspects. Chap. 2 In E. B. Eckel, editor, Ref. 10, p. 6-19.
26. Wood, R. C., and others. Soil, Water, and Suburbia. Proc. of a Conference Sponsored by the U.S. Dept. of Agriculture and U.S. Dept. of Housing and Urban Development, June 1967. U.S. Govt. Printing Office, 1968, 160 pp.
27. Woodring, W. P., Bramlette, M. N., and Kew, W. S. W. Geology and Paleontology of Palos Verdes Hills, California. U.S. Geol. Survey, Prof. Paper 207, 1946, 145 pp.
28. Young, Eleanor. Urban Planning for Sand and Gravel Needs. Calif. Div. Mines and Geology, Mineral Info. Serv, Vol. 21, No. 10, p. 147-150, 1968.
29. Záruba, Quido (editor). Engineering Geology in Country Planning. Proc. 23d Internat. Geological Cong. (Czechoslovakia), Sec. 12, 1968, 227 pp.