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Research at the U.S. Geological Survey on faults and earth fissures associated with land subsidence

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The vast areas of land subsidence induced by modern ground-water withdrawal in the San Joaquin Valley, California, and the Houston-Galveston area, Texas, are well known to most engineering geologists. In each of these areas more than 13,000 km^2 of land is estimated to have been affected by subsidence. In addition to these two large subsidence areas, the land surface within many basins in south-central and southeastern Arizona has subsided. Although the total area affected there is poorly documented, it probably exceeds 3000 km^2. On a national basis, about 22,000 km^2—an area approximately equal to that of New Jersey—has been lowered 30 cm or more by man-induced subsidence. Subsidence in excess of 1 m is common in most of the subsiding areas, and at one location in the San Joaquin Valley it exceeds 8 m.

As impressive as these figures are, they do not tell the whole story of the impact on the land surface from ground-water withdrawal. In addition to such effects as changes of surface gradients (affecting canals and drains), surface ruptures or ground failure are now recognized in most of the subsiding areas in the United States (Fig. 1) and in most places appear to be induced by the ground-water withdrawal. These ruptures range from long, open tension cracks or earth fissures to surface scarps or faults. Recent research by the U.S. Geological Survey has led to new insights into the failure processes. Prediction of their occurrence now appears feasible under some circumstances; however, some mysteries still remain. The following paragraphs describe these ground failures in more detail and review the results of the recent research at the USGS.

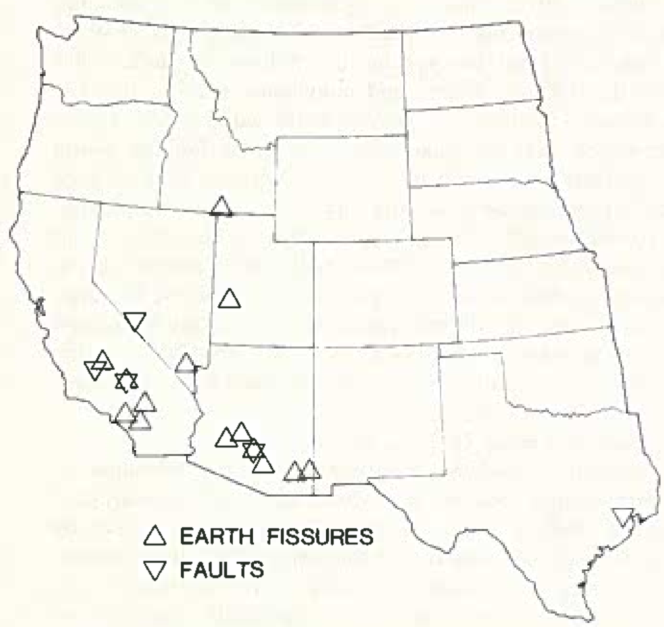

Fig. 1. Locations in the U.S. of ground failure associated with ground-water withdrawal.

Earth fissures can be very impressive visually because they commonly have lengths measured in hundreds of meters (e.g., Morton, 1976; Laney and others, 1978) and are dramatically enlarged to widths greater than 1 m by erosion from runoff entering the newly formed fissures (see Fig. 2). In fact, most fissures are first reported or noted after large surface runoff events caused by rainstorms. Their appearance is made more impressive by the transport and deposition of most of the eroded material far down into the fissures. The large void space inferred from the quantity of sediment deposited in fissures and the measured displacements associated with their opening of less than a few centimeters has led to speculation that many fissures extend to depths of tens of meters (Holzer, 1977). Although such depths have not been confirmed by observation, fissured sounded with weighted lines have commonly had open depths exceeding 10 m. At one location in Arizona, a depth of 25 m was measured by N. M. Johnson by this technique. Fissures occur either as isolated linear to curvilinear cracks or in complex systems of intersecting cracks. In a few areas, the fissures form polygonal systems similar in geometry to those in desiccated mud (Holzer, 1980a).

Because the several mechanisms that have been proposed to explain earth fissures should result in distinctive patterns of surface deformation near the fissures, the research program at the USGS has included a systematic monitoring of surface deformation based on closely spaced bench marks near fissures. The surface deformation we have detected indicates that linear to curvilinear earth fissures occur at zones of localized differential subsidence. The fissures are

Fig. 2. Earth fissure enlarged by erosion in south-central Arizona.

coincident with points of maximum convex-upward curvature in subsidence profiles oriented perpendicular to the cracks (Holzer and Pampeyan, 1979). Since we have also been able to measure horizontal extension at these points ranging from 100 to 70 microstrains per year, it appears that fissures are caused by stretching related to very localized bending of the alluvial overburden. In south-central Arizona, we have used gravity surveys to infer subsurface conditions beneath many fissures. We have found that fissures there are commonly located over convex-upward irregularities in the bedrock surface at the base of the alluvial aquifer from which farmers pump their irrigation water (Jachens and Holzer, 1979). This observation indicates that the localized differential subsidence observed near these fissures is caused by localized differential compaction related to variations in aquifer thickness. In addition to such variations, localized differential compaction can be caused by faults acting as partial ground-water barriers and by abrupt lateral changes in compressibility of subsurface materials. Hence, potential locations of fissures formed by a localized differential compaction mechanism can be predicted by conventional subsurface exploration. An indirect method of identifying such locations in areas undergoing water-level decline is to monitor surface deformation by precise surveying of closely spaced bench marks.

Whether a differential compaction mechanism applies to fissures forming polygonal systems remains to be demonstrated. Our investigation of polygonal systems to date has failed to detect any evidence for such a process. The similarity to mud cracks is suggestive of a desiccation process. In the case of the large polygons, the "drying" would be caused by water-table declines rather than air drying. If so, very large strains and presumably effective stresses are being mobilized in the unsaturated zone. Because deformation in the unsaturated zone is ignored by soil engineers in general, resolution of this problem may have wider application than just to formation of earth fissures.

In the early 1950s in the Houston-Galveston area in Texas, before land subsidence was a major concern there, a few geologists and engineers had become aware of creeping, aseismic, dip-slip faults that were causing surface deformation and structural damage. Today more than 150 historically active faults with an aggregate length of 500 km are areally associated with land subsidence there (Verbeek and others, 1979). Scarps locally exceed 1 m in height and can be traced at the land surface for distances as great as 16 km. Structural damage in the millions of dollars has resulted. Although a firm and convincing relation between the modern faulting and ground-water withdrawal has not been established, the predominance of active faulting within the confines of the subsidence bowl suggests that at least some of the modern activity may be related to ground-water withdrawal. The principal uncertainties come from the association of many surface faults with petroleum extraction, as well as from the possibility of tectonic faulting. Creeping, aseismic, dip-slip faults also are areally associated with ground-water withdrawal and land subsidence in the San Joaquin and Fremont Valleys in California, in south-central Arizona, Clayton Playa in Nevada, and in Mexico City and the Lerma Valley in Mexico.

Recently completed investigations of two examples of modern surface faulting in Arizona and California indicate that the modern faulting at these locations was caused by ground-water withdrawal. For these two faults the investigations suggest that modern movement was caused by differential compaction across pre-existing faults that behaved as partial ground-water barriers. We infer that differential compaction across a pre-existing fault plane caused shear failure (Holzer, 1978; Holzer and others, 1979; Holzer, 1980b). The cause of modern movement of the fault in California, the Pond-Poso Creek fault, was previously considered to be tectonic during investigations for a proposed power reactor that was to use ground water for a back-up water supply. In contrast, the evidence in the Houston-Galveston area suggests that preexisting faults there do not behave as significant ground-water barriers (Gabrysch and Holzer, 1977). Hence, even though the studies in Arizona and California indicate that faulting can be caused by ground-water withdrawal, it is not clear that the specific mechanism proposed for these faults applies to faults in the Houston-Galveston area. To address this problem, in 1978 the USGS initiated a systematic monitoring of surface deformation near faults in the Houston-Galveston area. Analysis of the strain fields near these faults may provide information on the specific mechanism of that faulting (Holzer and Thatcher, 1979).

In summary, ground-water withdrawal from unconsolidated sediments in the United States has caused surface deformation, including ground failure ranging from earth fissures to surface faults. Linear to curvilinear earth fissures appear to be caused by tensile strains induced by stretching of overburden related to localized differential compaction. Surface faulting appears to be associated with pre-existing faults and therefore represents a reactivation of geologic faults. Two faults studied in great detail in Arizona and California indicate that modern faulting was caused by localized differential compaction that was so discrete as to cause shear failure.

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CHAIRMAN'S MESSAGE

The membership advises that more action is appropriate

The April issue (1980, No. 2) contained a Straw Ballot and a request to the membership of the Engineering Geology Division for its guidance on what we should do about incorporating environmental geologic activities in our purview. As I write this (22 June), 111 separate votes have been received. Right now the percentages of response are as follows:

In favor of:	Percentage choosing
1. Status quo	4
2. Increased communication	22
3. Committee activity in environmental geology	31
4. Increase membership among environmental geologists	15
5. A change of name for EGD	21
5A. Definite opposition to change of name for EGD (not in percentage count)	5
6. A personal suggestion	7

We received ballots and thoughtful comments from our youngest and newest members as well as from our most distinguished and oldest members. As you can see, the majority of votes cast called for an increased tenor of activity in committees dealing with environmental geologic topics. Although 21 percent of the votes noted an interest in a change of name for the Division, five of those responding were vehement in their rejection of the idea. The truth of the matter came to light in a delightfully salty rejoinder from the Hudson River Valley, "If you try to be all things to everyone, you end up as a politician, not a geologist." Well, enough said. . . .

Well now, what will be the reaction of your Management Board? I believe that we can draw the easy conclusion that the status quo in this instance is not meeting the needs or assessment of the majority of the membership. Some directed move toward incorporating environmental geology to a greater degree in our Division activities is indicated. And, to answer this, the Board has asked Frank W. Wilson, Kansas Geological Survey, and past Management Board Representative of the Division to the Society, to chair an ad-hoc committee to take the ballots and associated comments and work up a plan of action. This plan will be submitted to the Management Board and interested visitors at the November meeting in Atlanta. Frank is known to many of us as the Past President of the Association of Engineering Geologists and as a man who has a strong and clear perception about the nature and role of Engineering Geology.

However, in the interim until Frank Wilson's report is due, there are some on-going activities which we will point out to the membership as evidence that the Division is moving toward a de-facto incorporation of things environmental. These activities are as follows:

Engineering Geology Data Sheets

At the suggestion of Professor Bernard W. Pipkin, University of Southern California, in November 1979 the

Management Board created a Committee on Engineering Geology Data Sheets. Response has been enthusiastic and Barney (impaled as committee chairman in recognition of his suggestion!) has collected a goodly number of candidates already. Two of the sheets appear in this issue of *The Engineering Geologist*. The Series, as you will note, is our informal extension of what we thought was the excellent but defunct American Geological Institute Data Sheet Series of the late 50s and early 60s. However, just three days ago I got a call from AGI Secretary-Treasurer (and AEG Past President) Richard J. Proctor of Los Angeles. Dick hastened to note that, strangely enough, the AGI Data Sheet Program was alive and well in a re-incubation effort under the aegis of R. V. Dietrich of Central Michigan University. Dick and the AGI group felt that they could give our data sheets a much wider exposure, helping, incidently, to further our involvement in the practice of applied geology. Therefore, the Management Board has worked out an agreement whereby Barney Pipkin will still collect and process EGD Data Sheets for printing in *The Engineering Geologist*. AGI has been given full publication rights for any of the series that it feels is of interest to the profession at large. Barney and contributors will compile the EGD Data Sheets according to the new AGI standards.

And, this is a place for a contribution by all EGD members in compiling these two-paged summaries of topical Engineering Geological data. Those selected will be printed back-to-back on single sheets as you will find in this issue. We'd like to hear from all members and would hope to receive these handy summaries of graphical, tabular, and written data relating to theory and technique applied to engineering and environmental geology.

Engineering Geology at the Sectional Meetings

Chairman-elect John S. Scott is in the process of contacting sectional meeting and program chairmen to ask them to consider holding sessions on engineering and environmental geology. Most of these folks will probably be receptive to that suggestion, but will ask "who do we contact to convene the session or to assist in selection of abstracts in engineering and environmental geology?". That's a fair question, and this is the precise point where you can enter. It's as simple as your writing or telephoning your section Contact Person, as shown below. Offer your services and/or abstract!

Cases-in-Point

Christopher C. Mathewson, Texas A&M University, has originated a Committee on Cases-in-Point—an activity designed to distill the essence of actual practice into tutorial briefs connecting problem with theory, with solution. Two of these Cases are being processed by Editor Bob Fickies right now; hopefully they will appear in issue no. 4 of our newsletter. Chris would be pleased to hear from you and will give you the specific actions for compiling your submittal. Many of us view this as a lot more fun than struggling to get a long technical paper out, and perhaps you will not have to suffer over whether or not your subject has a sufficiently unique appeal to "make the grade." Chances are that the regional geologic and physiographic controls over the problems will make them sufficiently interesting enough to start with! Many Cases-in-Point can be constructed directly from project reports compiled and written as part of your own practice. Chris is not particular about the specificity of location or project identification, and therefore you can be as vague about these data as your particular client confidence dictates.

So, as you can see, we *are* moving in a direction of increased involvement in those action-oriented aspects of the practice of engineering geology. Please do resolve to join with our speaking and writing contributors and make a statement to your brother and sister practitioners and to the geologic profession at-large!

Allen W. Hatheway
Cambridge, Massachusetts

Membership speaks via the straw ballot

Many of the EGD members taking the time to cast a straw ballot relating to the issue of involvement in environmental geology took the time to make some points for consideration by the Management Board. We think that there is much merit in these comments and wish to share them with you. To avoid a possible bombardment by brick bats, we've preserved a confidentialtiy with respect to authorship!

1. "I note in the *Abstracts with Programs* for the past few years that technical sessions are called either "Engineering and Environmental Geology" or "Environmental and Engineering Geology." In the six programs that I consulted, three listed it one way; three the other way. In no case did I find Engineering Geology and Environmental Geology listed separately. Based on the possibly unrepresentative data, I venture to guess that the profession has adopted de-facto acceptance of the titles of the overlapping disciplines.

A few years ago I might have resisted use of the word "Environmental" in the context of the geological sciences other than "environment of deposition," etc. I reviewed the AGI *Glossary* and find that Engineering Geology and Environmental Geology are defined on facing pages. My paraphrase of Engineering Geology is "the use of geologic principles to permit design and construction of safe and economical engineering works. My paraphrase of Environmental Geology is the use of geologic principles to permit intelligent and safe land use decisions. Environmental Geology, says AGI, "involves studies of hydrogeology, topography, engineering geology, and economic geology, and is concerned with Earth processes, Earth resources, and engineering properties of Earth materials. It involves problems concerned with construction of buildings and transportation facilities, installation of utility facilities, safe disposal of solid and liquid waste products, development and management of water resources, evaluation and mapping of rock and mineral resources, and overall long-range physical planning and development of the most efficient and beneficial use of the land."

From this description, it sounds like almost all professional geologists are practicing Environmental Geology . . . I prefer to have my title read "Engineering Geologist" on my business card."

2. "Engineering Geology is already so broadly based, it seems that it could presently be interpreted to include 'Environmental Geology.' Why not just so state?"

3. "Expand the use of the term 'Engineering Geology' to include Environmental Geology. Realize that the latter term often connoted negative thoughts as (to identifying such as, sic.) intervenors and obstructionists."

4. "Since Engineering Geologists are usually involved with projects designed by Civil Engineers, and C.E.s are now being renamed "Civil and Environmental Engineers," should not EGs follow suit?—not only in name, but *primarily* in scope?"

5. ". . . I had fully intended to let you [your chairman] have it between the eyes before now. . . . As you can see from the form (ballot), I do not believe it wise to add the name *Environmental* to *Engineering* and certainly not to *replace* the latter with the former. Admittedly, much of Engineering Geology is environmental in orientation, but then so is much of what the Quaternary Geology & Geomorphology Division and the Hydrogeology Division talk about in *their* sessions. So the Engineering Geology Division can't lay claim to all of Environmental Geology. On the other hand, Engineering Geology is largely an *applied* field as I see it, in contrast to the more fundamental slant of the QGG and Hydrogeology Division people. And this is good, because it emphasizes the differences between our 'environmental' and theirs."

6. ". . . I believe that Environmental Geology is Engineering Geology. Therefore, I would *keep* the division as the Engineering Geology Division and would open up our efforts to incorporate those geologists who call themselves Environmental Geologists. A Case History volume on the application of Engineering Geology in Environmental Protection would be a good idea." *Chairman's Note:* Do we have any takers?

Progress on LNG Siting Volume

Editors Jim Slosson (former California State Geologist; now Slosson & Associates, Van Nuys) and Jim Davis (California State Geologist) are actively pursuing compilation of an Engineering Geology Division volume dealing with geology in the siting of liquified natural gas facilities. The concept came from Management Board discussions with the authors at the Society's 1980 Annual Meeting in San Diego and in a few short months the authors' list has been firmed up for a three-part volume in the format of Review Volume IV (1979), dealing with nuclear power plant siting. The 20 candidate papers are listed below, along with presently assigned authors. The final author and paper list has not yet been finally established and the series of issue (Review Volume or Case Histories) has not yet been established. However, the volume comes at a time at which Federal siting regulations are just being issued and there is most interest for construction of such ports on the eastern and western seaboards of the U.S. and along the coasts of many energy-consuming nations around the world. Rough drafts are requested to be submitted to senior editor Slosson by 1 August 1980.

THE REGULATORY PROCESS

An overview of LNG facility siting and licensing . . . . Texeira/Ong (CPUC)

Development of geologic/seismic regulations and criteria . . . . Slosson

Geologic evaluation of LNG sites . . . . ?

Site review and evaluation of prospective LNG site . . . . . . Davis (CDMG)

Geologic criteria necessary for engineering design . . . . . G. Young (Agbabiab Assoc.)

Site selection and development . . . . Darrow (Dames & Moore)

California Coastal Commission review process . . . . Brogan (Woodward-Clyde); Tobin (Cal. Coast. Comm.)

Involvement of the intervener . . . . Asquith (Envicom)

Determination of geophysical risks . . . . Petak (J. H. Wiggins Co.); Wiggins

SEISMICITY

Seismicity of California . . . . Sherburne (CDMG)

TECHNIQUES

Application of photo interpretation to LNG site investigations . . . . Trieman (CDMG)

Application of remote-sensing data to LNG site investigations . . . . Krohn (Slosson & Assoc.)

Dating of soils in fault investigations . . . . Shlemon (Roy D. Shlemon & Assoc., Inc.)

Trenching as an exploratory method . . . . Patterson, et al (Dames & Moore)

Geophysics as related to siting of LNG facilities . . . . Gasch, et al (Gasch & Assoc. sub to Dames & Moore)

Measurement of in situ dynamic properties in relation to geologic conditions . . . . Yoakum (GeoSoils, Inc.)

Use of photography to record geologic data . . . . McClay (Slosson & Assoc.)

Pipeline geotechnical studies . . . . Moran (D. E. Moran, Inc.)

Fault dating techniques . . . . ?

Offshore analysis . . . . Pipkin (Univ. of So. Cal.)

Tom Fluhr has "retired"

Thomas W. Fluhr, long one of our underpinnings of the Division and early contributor to our publications (editor, with Robert Legget, of Reviews in Engineering Geology, Volume 1), has retired from active consulting. Tom is nearly 82, as he puts it. For over fifty years, Tom provided the engineering geology behind construction of New York City's mammoth water supply system. Several years ago, Tom and Vincent Terenzio, former Chief Engineer of the New York Board of Water Supply, completed a summary manuscript dealing with the geology of the New York City water supply systems. This material has not yet seen the light of day, aside from single copies furnished to the New York State Geological Survey and the New York Public Library. We understand that the New York State Survey may publish some of the material if Tom can "cut it down to about 250 pages." That leaves a lot of good residual materials relating to engineering geology in general. Tom may be open to suggestions as to what could be done with this as a service to the profession. For those without a copy of the membership directory, Tom's mailing address is P.O. Box 446, Liberty, New York 12754, but he notes that it's a chore for him to type. His phone: (914) 292-5096.

Hazards research in Arizona

The Arizona Bureau of Geology and Mineral Technology has received $30,000 through a cooperative agreement with the USGS to make a regional assessment of geologic hazards in the state of Arizona during FY 1980. A series of hazards maps (1:1,000,000 scale) will be produced, as well as a bibliography of Arizona hazards and related information. In addition, a photo file is being established to visually document historical events or potential hazards.

Population in Arizona (about 2.7 million) has increased sixfold since 1940. Urban development has spread across floodplains, "dry" washes, and into the mountain foothills surrounding Phoenix, Tucson, and communities that lie between them.

Seasonal flooding has resulted in loss of life and property throughout the state. No estimates of potential damage from mass movements exist. Slumping and creep are obvious problems in northern Arizona, especially in the vicinity of Flagstaff. Cracking of foundations, roads and utility lines have been reported from developments in Yuma, Tucson, Phoenix, Flagstaff, and several other population centers. The occurrence of expansive soils and other negative factors in foundation engineering have not yet been assessed on a statewide basis.

Two paleokarst surfaces resulting in earthcracks and enlarged subsurface fractures in the Plateau Province pose reservoir leakage problems. Continuing salt solution in Northern Arizona has caused large sinkholes. Subsidence and related earth fissures (some with vertical offset) have occurred in a few of the heavily pumped basins of Southern Arizona, most notably in the Eloy-Picacho region southeast of Phoenix. Differential compaction (consolidation) because of fluid withdrawal is expected to become an increasingly damaging phenomenon throughout rapidly growing populated areas of the Basin and Range Province.

Very little research has been conducted on seismic and volcanic hazards in Arizona. Sunset Crater erupted in 1065 A.D. Some of the state's seismicity is doubtless associated with the San Francisco volcanic field. The largest historical earthquake known to have caused damage in Arizona occurred May 3, 1887. A fault scarp with 2 m normal displacement and over 50 km length formed just south of the Arizona border in the San Bernardino Valley of Sonora. This earthquake (estimated magnitude 7.2) resulted in rockfalls as far north as Phoenix, building damage as far north as Tucson, and extensive ground failure and liquefaction in the extreme southeast portion of the state.

At the present time, recurrence intervals for such events cannot be adequately estimated. The possibility that a similar earthquake might occur north of the border, in Arizona, is of major concern.

Population is rapidly growing and industry expanding throughout the Sun Belt; therefore, knowledge of geologic hazards and associated land-use problems becomes increasingly important. Consequently, the following subjects are being researched: (1) hydrologic hazards (flashflooding, bank erosion, floodplain inundation); (2) mass movement (rockfalls, slides, debris flows, avalanches, creep, slump); (3) subsidence and/or collapse (from fluid withdrawal, solution weathering, lava tube caving, mining); (4) earthquakes (maximum historical intensities, frequencies, tectonic significance, epicenter locations); (5) volcanic hazards (lava flows, airborne ash, mudflow); and (6) foundation problems (expansive soils, caliche).

Compilation of existing data is underway. Economic loss figures will be solicited from various governmental agencies involved in disaster relief or general maintenance of facilities susceptible to natural hazards. The susceptibility maps will aid in focusing future research on significant problems. The Geologic Hazards Map Series should also prove useful to regional planners, consultants, and private citizens who presently do not have easy access to general information on this subject.

The maps will be designed to indicate the presence of and/or susceptibility to a particular hazard as determined from factors such as topography, type and thickness of material, geologic structure, and meteorological data. Flooding potential and subsidence maps will likely include man-induced parameters, such as reduced rainfall infiltration across concrete and asphalt surfaces and overdrafting of ground water. Historical incidence of flooding, collapse, volcanic and seismic activity will be displayed. Since the frequency of hazardous events cannot yet be estimated for most hazards, the map series will not designate risk factors. Inquiries or suggestions concerning the geologic hazards overview should be addressed to the principal investigator for the project, Susan DuBois, Geologist, at the Bureau of Geology and Mineral Technology, 845 N. Park, Tucson, Arizona 85719.

Report on CAES/UPHS short course

A short course entitled "Compressed Air and Hydraulic-Pumped Storage Development" was held December 3–7, 1979, at the University of Wisconsin, Milwaukee. Items of interest are

- High purity quartz sandstone are the most promising aquifers for CAES.
- Field behavior of hard rock caverns is dominantly influenced by vertical and horizontal stresses, discontinuity spacings, shear strengths parallel to joint and fault plane systems, and hydrologic influences such as hydrolytic weakening, slaking and lubrication.
- Shear zones can be improved by excavation and concrete filling, or by use of hardware reinforcements such as rock anchor bars, hollow rock bolts with grout, and post-stressed grouted wire tendons.
- The use of boring machines for cavern excavation instead of explosives would greatly reduce the potential for damage to the rock joint system.

TODD M. WEBER (1953–1979)

The Management Board is saddened by its duty to report the death of Todd M. Weber, alumnus of Rensselaer Polytechnic Institute. Todd was killed by a tragic accident while in the line of professional duties at an exploratory drilling rig on Long Island, 2 November 1979. In recognition of their son's love for and devotion to geology, his parents have established a perpetual scholarship at the Institute. Three students were selected on 3 April 1980 to participate in this living memory to a dedicated engineering geologist. The Division bids its young Brother farewell. . . .

EGD data sheet series begins

The Engineering Geology Division of GSA is pleased to present the first in a series of Engineering Geology Data Sheets to appear in the Newsletter. The sheets are patterned after the successful AGI Data Sheet Series, which began in 1947 and culminated 47 sheets later. Data useful to engineering geologists will appear periodically in the Newsletter beginning in this issue with Bob Fickies compilation of rock weathering and hardness terms. The sheets will be on the old AGI format so they can be inserted into a small six-hole binder for field use. Inquiries and suggestions for future data sheets should be directed to

B. W. Pipkin
Dept. of Geological Sciences
University of Southern California
Los Angeles, CA 90007

Cut on dotted line and trim as necessary.

GSA Engineering Geology Division

Data sheet 1

ROCK WEATHERING DESCRIPTIONS

Compiled by: Robert H. Fickies

New York State Geological Survey

Term	Description
Fresh	Rock fresh, crystals bright, few joints may show slight staining. Rock rings under hammer if crystalline.
Very slight	Rock generally fresh, joints stained, some joints may show thin clay coatings, crystals in broken face show bright. Rock rings under hammer if crystalline.
Slight	Rock generally fresh, joints stained, and discoloration extends into rock up to 1 in. Joints may contain clay. In granitoid rocks some occasional feldspar crystals are dull and discolored. Crystalline rocks ring under hammer.
Moderate	Significant portions of rock show discoloration and weathering effects. In granitoid rocks, most feldspars are dull and discolored; some show clayey. Rock has dull sound under hammer and shows significant loss of strength as compared with fresh rock.
Moderately severe	All rock except quartz discolored or stained. In granitoid rocks, all feldspars dull and discolored and majority show kaolinization. Rock shows severe loss of strength and can be excavated with geologist's pick. Rock goes "clunk" when struck.
Severe	All rock except quartz discolored or stained. Rock "fabric" clear and evident, but reduced in strength to strong soil. In granitoid rocks, all feldspars kaolinized to some extent. Some fragments of strong rock usually left.
Very severe	All rock except quartz discolored or stained. Rock "fabric" discernible, but mass effectively reduced to "soil" with only fragments of strong rock remaining.
Complete	Rock reduced to "soil." Rock "fabric" not discernible or discernible only in small scattered locations. Quartz may be present as dikes or stringers.

SOURCE OF DATA "Subsurface Investigation for Design and Construction of Foundations of Buildings," (1976) American Society of Civil Engineers, Manuals and Reports on Engineering Practice - N° 56

Data Sheet Committee
B.W. Pipkin, Chairman

May 1980

Association of Engineering Geologists Policy Statement on Disposal of High-level Nuclear Waste

John B. Ivey, President of AEG
Norman R. Tilford, Chm., AEG Nuclear Energy Committee

It is the position of the Association of Engineering Geologists that high-level nuclear wastes can be safely disposed of by deep underground burial in secure geological environments. The scientific and technical means to locate and define the boundaries of these environments and to achieve such safe disposal is well established. The Association distinguishes between safe storage of nuclear waste, which is primarily an engineering matter, and disposal of nuclear waste, which more directly engages the expertise of the engineering geologist. A national sense of urgency regarding safe disposal of nuclear wastes prevails, and it can and must be satisfied.

Disposal sites should be strategically located with respect to the regional distribution of nuclear facilities in the U.S. Each disposal site should be selected only on the basis of comprehensive studies to prove the best possible location within each region. Primary considerations in the selection of each disposal site must be long-term geological integrity of the host rock through natural retardation of radionuclide travel, and amenability to simple, proven, and reliable methods of engineered design and construction. Safe disposal sites can be found in igneous, sedimentary and metamorphic rocks. Technologies exist to ensure selection of disposal sites in these geologic media which can provide long-term integrity, without harmful effects due to leakage of radioactive materials to the biological environment.

Each disposal site should be selected and developed cooperatively by federal, regional and state entities acting on data acquired through private industry, with full and open disclosure as an integral part of the entire process to assure the protection of the health, welfare and safety of the public.

Status of geologic hazards in founding offshore structures

Robert L. Schuster, USGS, Engineering Geology Branch, Denver, has carried the 1980 Annual Meeting Symposium, "Geologic Hazards in Founding Offshore Structures," through to approval by the Atlanta Annual Meeting Committee. Bob has a panel of six speakers committed:

J. P. Hooper, McClelland Engineers, Inc., New Orleans
Louis E. Garrison, U.S. Geological Survey, Corpus Christi
R. J. Pottorf, Exxon Production Research, Houston
R. E. Smith, ARCO Oil and Gas Company, Dallas
Prof. J. M. Coleman, Louisiana State University, Baton Rouge
J. C. Hathaway, USGS, Woods Hole

Division members are reminded that this symposium and the subsidence symposium chaired by Tom Holzer are bonus dividends to the Division in addition to our authorized annual symposium chaired this year by Ted Smith and dealing with engineering geology in environmental planning.

GSA Engineering Geology Division
Data sheet 2

ENGINEERING DESCRIPTION
OF
ROCK HARDNESS

Compiled by: Robert H. Fickies
New York State Geological Survey

Term	Description
Very hard	Cannot be scratched with knife or sharp pick. Breaking of hand specimens requires several hard blows of geologist's pick.
Hard	Can be scratched with knife or pick only with difficulty. Hard blow of hammer required to detach hand specimen.
Moderately hard	Can be scratched with knife or pick. Gouges or grooves to 1/4 in. deep can be excavated by hard blow of point of a geologist's pick. Hand specimens can be detached by moderate blow.
Medium	Can be grooved or gouged 1/16 in. deep by firm pressure on knife or pick point. Can be excavated in small chips to pieces about 1-in. maximum size by hard blows of the point of a geologist's pick.
Soft	Can be gouged or grooved readily with knife or pick point. Can be excavated in chips to pieces several inches in size by moderate blows of a pick point. Small thin pieces can be broken by finger pressure.
Very soft	Can be carved with knife. Can be excavated readily with point of pick. Pieces 1-in. or more in thickness can be broken with finger pressure. Can be scratched readily by fingernail.

SOURCE OF DATA "Subsurface Investigation for Design and Construction of Foundations of Buildings" (1976) American Society of Civil Engineers, Manuals and Reports on Engineering Practice - No 56

Data Sheet Committee
B.W. Pipkin, Chairman

May 1980

Gartner Lee activities in Ontario

Submitted by John F. Gartner

The Ontario Geological Survey's Northern Ontario Engineering Geology Terrain Study (Ed. Note: to be the subject of a forthcoming brief by Owen L. White of the Ontario Survey) has been completed by a consultants joint effort. The 370,000 square kilometre area is the subject of a suite of more than 125 maps at 1:100,000. The purpose of the program has been to provide a common base of engineering geology terrain information for use by planners, engineers, administrators and all types of decision makers. Engineering terrain units were devised to describe the landforms in terms of origin, materials, drainage and morphology. Photogeologic interpretation was utilized to provide basic assessments which were then field checked over a three-year period. More than 12,000 panchromatic aerial photographs were interpreted in the course of the work. The maps will be a single-source of information for mineral exploration and logistical support activities, sand and gravel resources, land-use planning and development capabilities in general.

About 30,000 km^2 of southern Ontario are scheduled to be mapped in the 1979–80 continuation of the program.

Large-scale lignite exploration programs are once again underway in the Ontario northland as the Onakawana Formation, containing two beds of this newly emphasized energy source. The two lignite beds are separated by refractory-quality kaolin. These resources are believed to have been formed in the Cretaceous Era. Previous drilling efforts in the lignite had encountered sampling difficulties. However, with triple-tube coring and reverse circulation techniques borrowed from engineering geological site investigation techniques, the samples are being recovered. The area of investigation south of Moosonee, at the southern tip of Hudson Bay, is remote enough to warrant complete logistical support via helicopter. A 50-mile east-west cross section has been developed.

Interested in landslide problems?

The Japan Society of Landslides has invited American geologists interested in landslide problems to visit the most spectacular landslide areas in Japan during a 2-week period next October. The cost will be about $2,000. Anyone interested should contact

Earl E. Brabb, U.S.G.S., 345 Middlefield Road,
Menlo Park, CA 94025. Tel: (415) 323-8111 Ext. 2203

Long-term monitoring of stress levels near active faults

Bruce Clark has conducted 2+ years of measurements of stress levels along active faults in southern California under the National Earthquake Research Program. Results indicate that tectonic stress changes are occurring along the faults, and that the IRAD Vibrating Wire Stressmeters are capable of monitoring the changes. In southern California, the changes are small but well above the threshold of detection. The Stressmeter Net is deployed along the San Andreas and Sierra Madre fault systems north and east of Los Angeles. The four widely spaced sites have all shown a consistent build-up of compressive stress in the north-south direction relative to the east-west direction.

Not all sites show a new compression. For example, at Valyermo all horizontal stress change components are "decompressive," but the north-south quadrant shows the least decompression. This directional pattern of stress change matches both the tectonic setting and the results of surface strain measurement nets in the area. This same general pattern has been observed throughout the two years of monitoring. In addition to the long-term stress changes, instruments at San Antonio Dam showed an apparent co-seismic stress change during the group of earthquakes that hit the Imperial Valley and Lytle Creek in October 1979. Compressive stress increased approximately one bar in the north-south direction and decreased .5 bars in the east-west direction.

A new calibration study for the IRAD gauges shows that the level of pre-stress produced by wedging the gauges during installation is the controlling factor in determining the gauge sensitivity, rather than the numerical value of the reading. The higher the pre-stress level, the more sensitive the gauge becomes.

Construction aggregates in Saudi Arabia

Reid H. Brown, Truman R. Jones, Jr., and Peter V. Wiese,
Vulcan Materials Company, Birmingham, Alabama

Introduction

In recent years the Saudi Arabian government has committed major financial resources to the modernization and development of the country. Because of severe climatic conditions, logistical considerations, and Saudi Arabia's comprehensive development programs, this commitment has resulted in perhaps one of the greatest construction undertakings and challenges in recorded history. Reliable sources of suitable construction aggregates located within economic proximity to construction are a vital link for supporting a major construction program of this nature.

The rich oil fields of Saudi Arabia are located in the Eastern Province and are overlain with very young geological formations of sedimentary rocks. Because of the geological youth of these materials from which construction aggregates have to be derived and the climatic conditions under which they are used, great care has to be taken in the exploration, selection, production, and final use of aggregates from these sources.

Coarse Aggregates

The Eastern Province construction market will use approximately 30 million metric tons of crushed stone in 1980. This demand will be met primarily with materials produced from three major sources located near Abu Hadriyah, Dhahran, and Hofuf. These sources are located near the coast of the Arabian Gulf and are shown on the map in Figure 1.

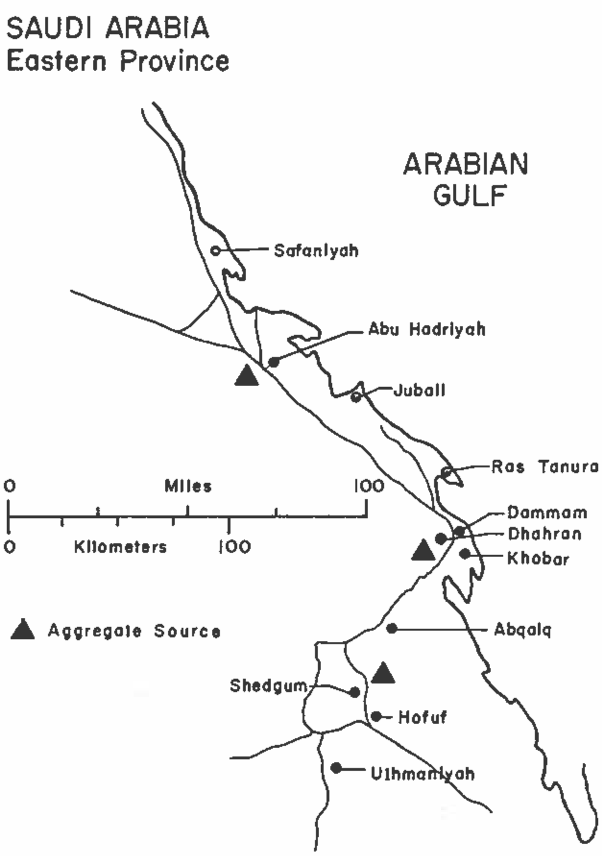

Figure 1. Location of coarse aggregate sources in the Eastern Province of Saudi Arabia.

Dhahran

Surrounding Dhahran is an outcrop of rock frequently referred to as the Rimrock. Because of its favorable proximity to the greater Dhahran, Dammam, and Khobar market, the Rimrock has become the major source of construction aggregate for that region even though the quality may be variable and marginal depending upon the care used to mine and produce it. The Rimrock structure is part of the Khobar Member of the Eocene Dammam Formation. It is composed of partly recrystallized limestone and dolomite intermixed with soft, marly limestone and shale.

There is reasonably good quality rock present in the Khobar Formation, but special care must be taken in the mining and production of crushed stone from this source or it may easily be contaminated with the marl, shale, and crusher dust. Experience has shown that it is advisable to crush material through a three-stage plant and to selectively waste the primary and secondary screenings as they contain most of the softer marls and shale.

There are two methods presently utilized in mining the Rimrock stone. Most of the smaller producers crush what can be ripped with a bulldozer. The larger producers drill and blast about a 20- to 30-foot face, which is the total useable thickness of the deposit. Generally, the ripped material is soft and of inferior quality.

Abu Hadriyah

Just south of the Abu Hadriyah junction along the Kuwait highway there is a thin cap of Miocene limestone covering an area of about thirty square kilometers. The stone in this area generally averages one meter thick with a range from 0.3 meter to 3.0 meters, about 30 cm of sand enclosed between each rock layer. The rock is mined primarily by ripping, but one operation has been permitted to drill and blast.

Most crushing is accomplished by jaw and cone crushers in the Abu Hadriyah area, resulting in an aggregate shape that is slightly flat and elongated, particularly for the minus one centimeter size material. When wet-washed, quality concrete with strengths up to 40 N/mm^2 (6000 psi) can be produced with this material. Gypsum and anhydrite particles are periodically found in the crushed rock.

Hofuf

There are two formations of stone located about 30 kilometers north of Hofuf that are presently being quarried. One of the deposits is in the valley floor adjacent to the Saudi Cement Plant, and the other is about 10 kilometers to the west on the Shedgum Plateau.

The cement plant deposit seems to be devoid of marl and shale, but the rock is softer and inferior to the harder rock found in the Rimrock or on the Shedgum Plateau. Gypsum, anhydrite, and other deleterious minerals have not been observed in this deposit.

The formation found on the Shedgum Plateau is a sandy limestone. Logistically, the Shedgum formation is more remote and thus has not developed the commercial interest as has the valley deposit.

Other Sources

As one moves westward and toward the interior of Saudi from the Arabian Gulf, the rock formations become geologically older and are of better quality. However, even with these materials certain unique properties frequently exist and may require special attention in processing and in their use as construction aggregates.

For example, there are several areas in which gravel can be found on the surface in layers that are one or two particles thick. These aggregates are the hard and weathered remnants of ancient washouts. Some of these deposits have been used for special projects in the more remote areas, but quantities are quite limited and the material is expensive to harvest because of its thin layers. Generally, the quality of these materials is suitable, but gradation compliance is often difficult to achieve because of the uniform size of the material. Petrologically, the gravel contains fragments of many rock types including quartz, limestone, chert, and igneous and metamorphic rocks.

Central Province

In the Central Province near the city of Riyadh numerous deposits of coarse and fine aggregates can be found in wadis. A wadi is a dry river bed which may have periodic flow of water during a heavy rain and runoff. The aggregates found in these wadis are generally in terraces and in the bottom of the wadis themselves. The rock is comprised of waterborne fragments of the harder stone formations from the wadi drainage area. They consist primarily of limestone, dolomite, and some quartz and different types of igneous and metamorphic rocks.

Generally, wadi deposit are friable, but some are bonded into a resistant duricrust as loosely cemented conglomerate. During dry seasons upward movement of ground water occurs carrying water-soluble alkali into the deposit. As evaporation proceeds, a caliche-like carbonate-enriched crust is formed bonding the alluvial material into a cohesive mass. It has been observed that isolated gypsiferous lenses occur in some of the wadi deposits and unless these materials are properly washed, this sulfate material may be harmful to concrete.

In addition to the wadi deposits found near Riyadh there are also some rather good limestone deposits. Certain portions of the Sulaiy Formation, probably of lower Cretaceous age, have been found to be suitable for construction aggregates. Because of the fractured condition of the in-situ rock, the rock breaks when crushed into a gradation that is basically one-size material. There are some parts of the Sulaiy Formation that have a high clay content and should not be used as a construction material. These argillaceous materials completely disintegrate when tested with sodium sulfate (ASTM C 88).

Both the wadi and the Sulaiy materials if properly processed are of better quality for concrete than are the aggregates found in the Eastern Province. Occasionally, engineers have specified Riyadh aggregates for special projects in the Eastern Province. Riyadh aggregates are expensive to ship into the Eastern Province (400–500 km), and their use is not necessary if a local source is properly selected.

SANDS

There are three sources of sands or fine aggregates available in Saudi Arabia for use in concrete and asphalt. In the Eastern Province dune sand is most widely used. Manufactured sand has been blended occasionally with dune sand in concrete mixes to improve gradations. Wadi sand is widely used in those areas where wadi deposits occur.

Dune Sand

Dune sands are widely found throughout the Eastern Province. They represent the only source of natural sands available for use in concrete. Even though they may appear by visual examination to be quite similar, there are unique differences in some of their physical properties that affect the properties of portland cement concrete. Dune sands are much finer than generally accepted concrete sands.

In selecting a dune sand for use in concrete there are several factors that must be evaluated. Dune sands located on sabkha (a low flat area with a high salt-water table) should be avoided because of the contamination that will likely occur. Occasionally, sands are also contaminated with marl, asphalt, and other organic materials.

It has been reported that the more rounded wind-blown particle shape often found in dune sand reduces the strength of concrete. Our experience has not verified this concept. Gradation and cleanliness are the two most important factors in the proper selection of a dune sand. Dune sands have between 90 and 95 percent quartz and the remaining mineral is calcium carbonate.

Dune sands are void in the 4.75 mm (#4) by 1.18 mm (#16) size fraction which causes a gap in the total gradation of aggregate for concrete mixes. Because of this gap in gradation, and the fineness of the sand itself, mix designs require certain modifications so that they can be appropriately used.

Wadi Sand

A high quality sand can be produced from many of the wadis near Riyadh. Generally, these sands contain clay and silt which require some form of classification and, if feasible, washing to remove deleterious materials and improve gradation. Since water is scarce, most sand classification is accomplished by dry procedures either through screening or air classifying. Concrete made with wadi sands washed in the laboratory have exhibited excellent strength properties. Most wadi sands are a combination of carbonate and quartz particles.

CONCLUSIONS

During the past four years Vulcan has produced in Saudi Arabia over 2 million cubic meters of high quality concrete. The concrete, in strength classes of 20 N/mm^2 (3000 psi) and 28 N/mm^2 (4000 psi), has consistently complied with the specification standards of the design engineers and the American Concrete Institute (ACI) 318 Building Code. It has been used throughout the Eastern Province in major structures such as industrial facilities, power plants, high-rise buildings, schools, hospitals, etc. The coarse aggregate for most of this concrete has been crushed stone from the Rimrock quarries operated by Vulcan. The sands were selected from dunes meeting established requirements.

The success of this operation is attributed primarily to applying the principles of good materials technology to all aspects of production: geological exploration, coarse aggregate production, sand selection, specification cement procurement, and quality control over concrete production.

Acceptable quality portland cement concrete can be produced in Saudi Arabia if correct technical and production considerations are given proper attention and effort through all phases of developing a material resource—exploration, material evaluation, plant design, and production control.

COMMENTS FROM THE MEMBERSHIP

"Word from Wyoming"

I commend your efforts in establishing a dialog among members of the Division. Si ce we share a common bond—the interest and professional involvement in engineering geology—it is essential that we communicate. The annual and regional GSA meetings are beneficial, though certainly not the answer to fully communicating the interests of the Division.

Another area I shall comment on is the matter of consolidating environmental geology within the Engineering Geology Division. I support this concept because the two areas compliment one another. The environmental geologist and the engineering geologist rely, or should rely, upon one another in solving the environmental geology problems facing this nation. I see the combining of the two areas under one division as beneficial.

Collin Fallat
Natural Resource Analyst
Office of the Governor
State of Wyoming

"Report from the Pacific Northwest"

One of the most intensively investigated areas at the present time is the Hanford reservation in the Columbia Plateau. Three nuclear plants are now under construction and a great effort is being made to find a site for nuclear waste disposal. Perhaps 40 or more geologists are presently working in the Columbia Plateau and particularly at Hanford. The 21 public utilities in the state are constructing the nuclear plants. Four private utilities are looking for nuclear sites in or near the reservation.

The Department of Energy is spearheading the studies for waste disposal sites and has contracts with Rockwell Hanford, Battelle, the State Geological Survey, etc. The U.S.G.S. also is cooperating in the studies. A recent product of this effort is the publication of 12 colored geologic maps at a scale of 1:62,500 of the Hanford Reservation and environs. This was put out by Rockwell Hanford Operations (Richland, WA 99352).

The fascinating part of this effort is the bringing together of so many disciplines to unravel the secrets of the Columbia Plateau structure. Thousands of square miles of air-mag have been flown. Gravity maps have been prepared using thousands of stations. Seismic investigations include vibro-seis, refraction and reflection methods. Fortunately the hundreds of deep drill holes provide confirmatory evidence for plotting the seismic profiles.

The U.S.G.S. has been making analyses of the basalts for many years so it is now possible to identify each basalt flow on the basis of its chemistry, petrography or gross physical features.

The public utilities have used such consulting firms as Shannon and Wilson and Woodward-Clyde for many years to investigate the geology, seismology, structure, and remnant magnetism of the Hanford area. They also employed Weston Geophysical Research to carry out the seismic investigations and interpretations as well as the air mag and gravity studies.

Rockwell Hanford Operations and their earlier counterparts have made hydrologic studies for years and have a remarkable computer program for identifying various aquifers and aquacludes.

Unfortunately much of this information is buried in PSAR's for the Utilities and the numerous amendments to the PSAR's. Some of the results are finally getting out as abstracts for GSA meetings and undoubtedly more will follow but perhaps at a slow pace. Only now are we beginning to put all this information together to make a structure model for the Columbia Plateau.

My part in this work is chairman of an advisory committee for the private utilities. The members of the committee are: Richard Holt, Weston Geophysical; Gene Simmons, MIT; Joe Vance, Univ. of Washington. For the public utilities, Greg Davis of U.S.C. and I share the position of advisors. During the past two years I worked with Battelle on a computer analysis of the structure of the Columbia Plateau. Many others worked with Battelle on various aspects of waste disposal.

Howard A. Coombs
University of Washington, Seattle

"From the South"
Subsurface formation logging

I am employed by Dresser Industries, Dresser Atlas Division, as a technical representative. In our association with mining and petroleum, several types of circumstances require Dresser to provide information on formation lithology and mechanical strength. In coal mining, formation strength is directly required to estimate production considerations of roof support, floor strength, seam mining technique, strippability, and such things as moisture and ash content. In the petroleum industry, the ability of the formations through which a well is drilled to withstand and sustain the drilling can be determined and mud programs revised for better efficiency. In producing oil and gas, a reservoir rock's ability to resist "sanding" of "fine" into a producing well can be determined through standard equations of elasticity.

Young's Modulus, Bulk Modulus, Shear Modulus, and Poisson's Ratio are computed from bulk density, acoustic travel time, and induction electric (for water saturations), the use of Neutron porosity is required for lithology analysis. With these measurements, a determination of lithology formation strength can be made for use in deciding on minirg options and gravel packing of oil and water wells.

John Puffer
Dresser Atlas Division, Dresser Industries
New Orleans, Louisiana

Southern California

At 47, I have just started back into geology with a small civil engineering firm, concentrating on foundations for residences and other lightly loaded structures. Here in Southern California, seismic hazards are well recognized. A rapidly expanding population is pushing more into marginal lands and surfacing the extent and importance of landslides. Three years of abnormally high rainfall have contributed to numerous failures in places thought before to be stable. This without significant seismic triggering.

This accentuates an area we have left largely to Civil Engineering. Slope stability and slide potential evaluations can be an essential part of investigations. An excellent local report on this problem came to my attention recently. It is:

Cleveland, G. B. (1975) *Landsliding in Marine Terrace Terrain*, Special Report No. 119

It can be obtained from California Division of Mines and Geology, 1419 Ninth Street, Sacramento, Ca 95814. Cleveland correlates slides with changes in stream erosive power associated with sea level changes. It is an interesting approach which could probably be applied to other base level changes.

We need a strong Division to promote *applied* geology. I would be happy to help organize and extend our efforts in the San Diego area.

David Phifer
Tri-City Engineers, Vista, California

REPORTS •

Report on conference, "Geotechnology in Massachusetts"

Professor Oswald C. Farquhar, University of Massachusetts, and a member of EGD, has convened and completed a two-day conference, "Geotechnology in Massachusetts." The meeting was held at the Boston Harbor campus of the university on 20-21 March 1980 and was attended by some 450 persons. Oswald took pains to reach a broad audience, and those attending were representative of a broad geological, geotechnical, physical science, media and government at all levels. As indicated by the conference title, the 76 papers delivered at one to three contemporaneous sessions spoke of real problems facing New England and some reasonable solutions that are now being implemented. Among the many categories of papers were those dealing with the following:

New state-wide geological maps of Massachusetts
Ground-water studies and ground-water pollution
Terrain assessment and specialized geologic mapping
Rock mechanics applied to tunnels
Underground storage caverns
Geotechnical property determination
Applied geophysics
Hazardous and special waste disposal
Regional energy sources
Regional seismicity
Economic mineral deposits
Coastal and island processes
The Outer Continental Shelf at Georges Bank
Offshore siting

EDG members were well represented across the breadth of the conference. Dr. Farquhar has already begun to press forward with preparation of a proceedings volume to follow in the fine tradition of his 1965 volume, *Economic Geology in Massachusetts.*

Report on U.S. National Committee progress

Your Management Board, along with the Executive Council of the Association of Engineering Geologists, has worked closely for the past four years on the matter of forming a United States National Committee for Engineering Geology. Most of the work and progress to date has been due to the efforts and abilities of former EGD Chairman David J. Varnes. The USNCEG will represent this nation as an integral part of the International Association of Engineering Geologists. The United States is the last major nation without a national group for engineering geology. We have gained support from the U.S. National Committee on Geology, represented by its Secretary, Dr. Linn Hoover, U.S. Geological Survey, Reston, Virginia.

EGD Past Chairman Richard H. Jahns and AEG Past President, Richard J. Proctor, have chaired a nominating committee to forward a slate of names to Dr. Hoover for consideration in making up the organizing committee for the USNCEG. Dave Varnes is working closely with the USNCEG and reports that the important fomenting details should now be complete in time for creation of the USNCEG at the forthcoming International Geological Congress, being convened in Paris in July of this year.

Creation of the USNCEG will provide a means for EGD members to join IAEG and receive its excellent *Bulletin* at special dues rates of less than $12 per year.

Report on the 3rd International Congress, "Deterioration and Preservation of Stone," Venice, Italy, October 24-27, 1979

Venice, Italy, offered a perfect setting and timing for a four-day conference with a tight schedule of single sessions. The first day was devoted to weathering, followed by papers on the influence of the atmosphere on stone, especially by sulfates; several papers dealt with the catalytic action of marble surfaces on sulfate, a repetition of a paper previously published in the journal *Atmospheric Environment.* Though the selection of the papers was in the hands of the section chairmen, considerable duplication of efforts was noticed. Case studies and case histories on stone preservation dominated the remaining sessions. I contributed two papers, "Effects of Case Hardening in Stone," and "Convex Warping of Flat Lying Marble Slabs in a Polluted Atmosphere on Humid Tropical Curaç, Dutch West Indies." Restorators, restoration architects, chemists, and petrographers presented their experience and exchanged ideas in a truly fruitful interdisciplinary fashion. Nothing new was reported at the meeting, neither on stone decay nor on new methods of stone preservation. The meeting was sponsored by the University of Venice, the University of Padova, and the Institute of Oceanography at Boulogne, France. Professor L. Marchesini of the Instituto di Chimica Industriale of the University of Padova was the president of the congress; Dr. G. Natile of the University of Venezie, the secretary.

About 300 participants contributed 80 papers, mostly from Italy, France, and West Germany; only 6 Americans, two of them geologists: L. K. Gauri, Univ. of Louisville, and myself. From the East Block only East Germany sent one representative; papers of delegates scheduled from Poland, Czechoslovakia, and Hungary had to be cancelled and were substituted by some others.

A hefty $125 for registration included the program, a booklet with the submitted abstracts, and a ticket to a pleasant banquet at Cipriano's on the island of Torcello near Venice. A field trip to the cleaning operation of early Christian mosaics in the ancient basilica of Torcello remained without a leader, a guide of any kind. Interested participants had to mix with small tourist groups, several of which were fortunately conducted in English. In addition, an unofficial trip was promised to visit successfully preserved monuments in Venice, but the information desk knew of no such trip.

I had the opportunity to visit the Freiburg Cathedral in West Germany under restoration, as well as other places in the Black Forest, a fine compensation for the deficiency in Venice.

P.S. The well-organized and well-functioning national and regional meetings of the GSA, AEG, and many other meetings are memorable events which have somehow spoiled the American participants. My post-conference travels caused the loss of my book with the abstracts, and to this day it has been impossible to obtain a replacement copy from either the secretary or the president of the congress, despite repeated requests.

Erhard M. Winkler, Department of Earth Sciences, University of Notre Dame, Notre Dame, IN 46556

Report on Centennial Committee activities

You may recall that Rev. Dr. James W. Skehan, S.J., was appointed by your Management Board at the San Diego meeting to chair the standing committee on "GSA Centennial Participation by EGD." We are happy to report that, as of April 1980, Jim had gathered together committee members and has already forged a direction and some tentative prospects. His committee consists of EGD former chairmen Ed Eckel (1954), Robert F. Legget (1959), Jim Skehan (1976), George White, Artl. ; Socolow, and Allen Hatheway.

The tentative lines of activity that the committee has produced to date are (1) the 1981 EGD Annual Symposium on "Development of Engineering Geology in the Federal Agencies," followed by (2) development of papers on that subject, for inclusion in (3) a centennial volume dealing with the "History of Engineering Geology in North America," to also include (4) papers originating from subsequent annual symposia expanding the historical coverage of the volume under compilation, and (5) discussions relating to possible compilation of a volume of definitive papers on the practice of engineering geology in the 1980s.

We think that the main thrust of the Centennial activity by the Engineering Geology Division will be mapped out for decisions by the Management Board at Atlanta, and that the membership will be given a comprehensive report in *The Engineering Geologist* early in 1981. Ideas and suggestions will be welcomed by Jim Skehan at Weston Observatory, Boston College, Weston, MA 02193. Please let Jim know what you feel will be appropriate.

Geologic erosion: A first level determination

Earl P. Olson, Regional Environmental Geologist, U.S.D.A. Forest Service, Intermountain Region

One of the lamentable defects of watershed management has been the unmeasured aspects of geological erosion. Accordingly, this brief note describes a suite of techniques which have been adapted to measure geologic erosion for a first level determination.

Environmental Geologists of the Intermountain Region have for the past decade been developing monitoring equipment and specialized techniques to substantiate and track management decisions that deal with erosion in mountainous terrain. Since 1912, management and formal research has been concerned with land erosion in the Intermountain Region. This central concern is necessitated by the complex mountainous terrain that makes up the Intermountain Region of the U.S.D.A. National Forest Service System. There are two broad types of geologic materials that must be monitored in geologic erosion studies: consolidated or cemented materials and unconsolidated materials.

I. Consolidated or cemented materials

There are four erosion-susceptability material tests that are performed under this heading. Two are performed in the field and two in the laboratory.

Test 1. This test utilizes the Schmidt Hammer (type L) as a measure of rock strength. The Schmidt test, along with aliquot sampling for weight per unit volume, and slacking, are performed in a ring of influence 30 to 200 mm in diameter. Aliquot samples from the ring of influence are the size of a walnut to the size of a fist. These samples are labeled and submitted for tests 2 and 3.

Test 2. This test determines weight per unit volume. The weight is the measurement of an oven-dried aliquot sample, and the volume is measured by the mercury displacement technique.

Test 3. This test is a slacking test. It is run on one or two cycles. The oven-dried sample is placed in distilled water for ten minutes. The weight loss passing the 2.0 mm sieve for either one or two cycles is the slacking test (see Aufmuth, 1974). Dr. Aufmuth's approach has been modified slightly to better serve the purpose of first level determination of geologic erosion:

Slacking Test Categories

Loss		
0–10 percent	Low	
10–50 percent	Medium	Specify one or two cycle test, as used
50–90 percent	High	
90–100 percent	Complete	

Test 4. This test is performed in the "eye" of the ring of influence, 30 mm in diameter. This is an averaged micrometer measurement of surface erosion and is recorded in concurrent 2- and 5-year cycles.

The "High" and "Complete" slacking categories cited above have generated landslides in the multimillion-cubic meter category in Late Pleistocene time. Over two hundred of these landslides have been mapped in about eighteen percent of the thirty-one million acres of the Intermountain Region. A larger number of landslides probably yet remain to be mapped. The "High" and "Complete" slacking units generate high rates of geologic erosion in the contemporaneous environment. Due to the arid climate of the Intermountain Region, only certain precipitation events will generate sufficient sediment to make a serious impact on the land.

II. Unconsolidated materials

Unconsolidated materials are also measured by the four conventional tests. Replication of all the tests is performed from initial sites and sites of similar stratigraphy, but located at different altitudes and climatic zones.

It is anticipated that within five to seven field seasons that our working hypothesis that erosion or disintegration of mountains is proportional to altitude will be tested. Also, the working hypothesis that strained minerals disaggregate more rapidly than nonstrained minerals will have been tested.

The current level of study is on a functional basis. However, it is anticipated that a procedural guide for estimating geologic erosion potential will be available in about a year. The studies will then shift to an inventory basis.

In summary: the tests on consolidated or cemented materials and on unconsolidated materials provide significant progress in the measurement of geologic erosion on a first level determination in the Intermountain Region.

Reference

Aufmuth, R. E., 1974, Site Engineering Indexing of Rock: American Soc. for Testing and Materials STP 554, Field Testing and Instrumentation of Rock, p. 81–99.

Approaches to environmental geology in New Mexico

by John W. Hawley[1]

Environmental geology is "the application of geology, geologic techniques, and geologic reasoning to the broad environmental concerns of society. The terms are not, nor should not be, precisely defined. Environmental geology is clearly not a subdiscipline of geology, but it does embrace a large involvement and wide application of geology (Fisher, 1974, p. 1)." Emphasis is on solving problems arising from modern society's intensive use of the earth. This means putting geologic processes and their products into proper perspective in terms of space, time, and human affairs. Geologic processes can include the action of deep-seated forces that cause volcanic eruptions and earthquakes or surface phenomena related to interactions of the atmosphere, biosphere, and hydrosphere with the lithosphere. Geologic products include both material units and the land-surface forms produced by geologic processes.

Converting investigations of the geologic environment into environmental geology also involves a switch to a forward-looking approach that uses the past and the present as keys to the future. Above all, successful application of our expertise to help solve environmental problems of today and tomorrow demands effective communication. What we know, what we infer, and degrees of uncertainty must all be clearly expressed. Our success should be measured in terms of nods of understanding from planners, politicians, and plain-old-persons as well as from our peers.

Examples of approaches to environmental geology used in New Mexico are outlined below. However, it should be clear that many categories defy rigid placement in any sort of hierarchy. Workers come from many professional areas, private and public. Subdisciplines represented include engineering and petroleum geology, stratigraphy and sedimentology, geomorphology and hydrogeology, and economic geology.

I. Physical environment of broad areas for regional planning.
  - A. General purpose mapping of landforms, earth materials, and geologic structure at 1:250,000 and smaller scales.
  - B. Broad-scale special studies.
    1. Surficial geology and aggregate-resource mapping for state and federal highway projects (N.M. Highway Dept.)
    2. Statewide evaluation of geologic hazards—processes and conditions that could result in harm to people and property (earthquakes, landslides, and subsidence).

II. Studies of specific problems or local areas.
  - A. Geologic hazard assessment.
    1. Earthquakes and associated deformational features, such as faults ad fissures, resulting from seismic activity.
    2. Volcanic eruptions (prehistoric activity in state).
    3. Landslides and related mass movements such as debris and mud flows.
    4. Subsidence due to human or natural causes, exclusive of seismic activity (e.g. differential consolidation of basin fill upon withdrawal of ground water, solution subsidence in evaporite and carbonate rock terranes, mine-roof collapse).
  - B. Waste disposal site selection.
    1. Sanitary land fills for urban and domestic sites.
    2. Hazardous-waste disposal sites.
       a. Non-radioactive waste—near surface sites
       b. Radioactive wastes—near surface sites
       c. Radioactive wastes—deep subsurface sites.
  - C. Site selection for preservation of unique natural phenomena.
    1. Scenic and geomorphic-process sites (e.g. Rio Grande Gorge, White Sands, Carlsbad Caverns).
    2. Geologic history sites (e.g. San Juan Basin fossil beds).
  - D. Site selection for power generation and transmission facilities (e.g. nuclear power plants), and pipelines.
  - E. Development of mineral resources; long-term objectives should include protection of resources from incompatible land use as well as implementation of responsible resource exploitation with due consideration for the environment.
    1. Water resources (only in part renewable).
    2. Non-renewable resources, primarily oil and gas, coal, potash, uranium, copper, molybdenum, gypsum, and aggregate materials. Environmental activities to date mainly concerned with oil and gas conservation, and reclamation of surface coal-mine areas.
  - F. Geology for urban planning (e.g. ongoing work in Albuquerque area; needs expansion into new areas).

III. Some areas of basic research relating to current and future problems.
  - A. Geomorphology with emphasis on surface processes and Quaternary history; gives time and space perspective on distribution of dynamic and relict processes and landforms. Problem areas include natural vs. accelerated erosion, non-point-source sediment pollution, and reclamation of surface-mined land. Broad geomorphic-process categories include:
    1. Fluvial systems.
    2. Eolian systems.
    3. Lacustrine systems.
    4. Ground-water systems.
    5. Mass-wasting systems.
    6. Mountain glacial systems.
  - B. Geology and geomorphology with emphasis on deep-seated processes, and associated materials, structures, and surface forms. Combined input of geology and geophysics has direct application to assessment of earthquake and volcanic eruption hazards.
  - C. Geochemical research applicable to II B, E, and F.

Reference

Fisher, W. L., 1974, Approaches to environmental geology, *in* Wermund, E. G., ed., Approaches to Environmental Geology: Texas University Bureau of Economic Geology, Rept. Inv. 81, p. 1–2.

[1] Environmental geologist, New Mexico Bureau of Mines and Mineral Resources, Socorro, NM 87801. January, 1979.

Geotechnics in steel development projects in Nigeria

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Nigeria intends by 1983 to establish 2 steel plants and 3 rolling mills to ensure ranid industrialisation and to diversify the economy. One of the steel complexes, the Ajaokuta Blast furnace, is a Nigerian project with technical assistance and cooperation from Tradjmoexport of Soviet Union while the Direct Reduction Operation situated at Aladja near the port of Warri is being executed by a consortium of German and Italian firms.

Efforts at steel development in the country culminated in the establishment of a Steel Authority in 1971 as a body charged with the responsibility for exploration and exploitation of raw materials required for the Ajaokuta Steel Plant. Engineering geology has found wide application in this project in 2 main aspects:

First, in pre-mining studies, such as for open pit iron and underground coal mines. Second, in foundation engineering for large structures.

Exploration for iron ore, a vital raw material to the steel plant, started in the Okene-Lokoja area in 1973. More recently engineering classification tests commenced on the iron ores and the granitic/gneissic host rocks. This was followed by detailed slope stability investigations on overburden, trenches, and road cuts in the mine area along with documentation of exploratory adits and pilot mines. Permeability and water pressure tests are being carried out to determine the rate and amount of water ingress in the mine area with an analysis of discontinuities (fractures, joints, and faults) based on fracture spacing index, rock qualtiy designation and other structural information from oriented cores.

Exploration for coking coal in the Lafia area revealed 2 economic seams occurring at relatively great depths. This has necessitated in-seam exploration along a set of boreholes as well as in-situ engineering and weathering tests with observations of the stand-up time of roof and floor measures of the coal seams. An understanding of the geotechnical data available has enabled an identification of possible problems such as swelling or squeezing ground and underground water in the design of adequate supports for the mine. In Nigeria, engineering geology has continued to make significant contributions in routine foundation studies but in this case for large structures such as for the steel plant site, base camps or mining towns.

A fairly recent development is the invaluable role engineering geology is assuming in environmental protection and management particularly in ascertaining the influence of man's activities resulting from inevitable industrialization and large construction projects.

Thus, with few indigeneous personnel, engineering geology contributes immensely to the industrial take-up of developing Nigeria.

PUBLICATIONS OF INTEREST

Hydrology of areas of low precipitation subject of new publication

Canberra, Australia, was the site in December 1979 for an International Symposium on Hydrology of Areas of Low Precipitation. The symposium was sponsored by the International Association of Hydrological Sciences (IAHS) and the Australian National Committee for Hydrology. The technical papers from the symposium are now available for purchase from the IAHS.

The symposium proceedings volume of 502 pages contains 50 technical papers by outstanding specialists from 17 countries. The scope of the volume is very broad, covering state of art, theory, laboratory and field research, and practical case histories on the following broad subjects: (1) Streamflow characteristics with special reference to low and high flows, (2) Quantitative and qualitative aspects of the relationship between surface water and subsurface water, and (3) Effect on sediment production of land use and management.

The symposium proceedings, published as IAHS Publication No. 128, sells for $60, U.S. Orders should be sent to W. W. Hastings, Treasurer, International Association of Hydrological Sciences, 2000 Florida Avenue, N.W., Washington, DC 20009.

The Magnificent Gateway, Professor Emeritus John Eliot Allen, Portland State University, Portland, Oregon, 1979.

Dr. Allen's new paperback is priced at $7.95 (plus $0.50 postage) and is the new standard reference for travelers along the Columbia River Gorge, which for its bare slopes on the east and high cliffs to the west is good ground for seeking out engineering geological features affecting highway and railroad construction as well as the dams and bridges built to span the Columbia. Order it from Timber Press, P.O. Box 92, Forest Grove, OR 97116.

Environmental Geology, Professor Donald R. Coates, SUNY at Binghamton.

We have learned that Don has written the text and that it is being readied by John Wiley & Sons for possible release at the GSA Annual Meeting in Atlanta, come November. Based on his long-standing immersion in applied geomorphology and environmental geology, Don might have a lot to say to the practitioners too!

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