



THE  
GEOLOGICAL SOCIETY  
OF AMERICA

# The Engineering Geologist

THE QUARTERLY NEWSLETTER OF THE ENGINEERING GEOLOGY DIVISION OF THE GEOLOGICAL SOCIETY OF AMERICA

Vol. 1, No. 2

July 1966

## FOUR EGD FIELD TRIPS PLANNED FOR GSA ANNUAL MEETING

A full program of engineering geology field trips has been planned for the GSA Annual Meeting in San Francisco this November. The EGD-sponsored trips, numbers 10-13 in GSA's Circular 1, include a wide range of geological and engineering features of great interest and importance. Elmer Marliave, who has done the lion's share of the planning, has furnished the following description:

### Field Trip No.10. Saturday, November 12. Tehachapi Pumping Plant.

Trip will begin with a bus to the airport and a flight to Bakersfield with the first couple of hundred miles following the San Andreas Fault, then crossing the Tumbler Range, and along the preconsolidation settlement ponds on the California Aqueduct system. There will be a bus trip to the Tehachapi Pumping Plant area and underground discharge lines, where excavation for the plant and an adit is under construction in the vicinity of the surge tank location. The return flight will be along the west side of the San Joaquin Valley, along the alignment of the California Aqueduct and the San Luis Project.

Leave San Francisco about 6:15 a. m., have breakfast at the airport on your own, and return about 7:30 p. m. Estimated Cost: \$35.00, including a box lunch and guidebook. Trip leader will be A. B. Arnold of the California Department of Water Resources. NOTE: We are sorry that women will not be permitted to go underground.

### Field Trip No. 11. Saturday, November 12. San Luis Dam.

Trip begins with a flight along a short portion of the San Andreas Fault to a point to the west of Los Banos to visit the San Luis Dam and Pumping Plant. From there on, transportation will be by bus. The local features will be examined as well as the San Luis Forebay. We will return along the California Aqueduct alignment and Delta Intake Pumping Plant. The trip will leave San Francisco by bus about 6:15 a. m., breakfast on your own at the airport, and return about 6:00 p. m. Estimated Cost: \$20.00, including box lunch and guidebook. Trip leader will be a geologist of the U. S. Bureau of Reclamation.

Field Trip No. 12. Saturday, November 12. Oroville Dam.

Bus to the airport and then an airplane flight to Oroville along a very short strip of the San Andreas Fault and along a portion of the Hayward Fault en route to Oroville. Bus trip to Oroville Dam, Pumping Plant, and Thermalito Afterbay. This trip will be to one of the largest and highest dams in the country currently under construction. Leave San Francisco about 6:30 a. m. , breakfast at the airport on your own, and return about 6:00 p. m. Estimated Cost: \$20.00, including box lunch and guidebook. Trip leader will be A. L. O'Neill, Project Geologist for the California Department of Water Resources.

Field Trip No. 13. Sunday, November 13. Bay Area Cruise.

Leave about 7:30 a. m. after breakfast on your own in San Francisco. Bus to the Bay Front, board the pleasure boat for a cruise of San Francisco Bay and a description of the BART (Bay Area Rapid Transit) Project, with views of the caissons and a description of the method of laying the tubes underwater. This field trip will include a choice of two side trips in the afternoon.

Side Trip No. 1: Bus from Oakland to the BART Berkeley Hills Tunnels, which are under construction. Return to San Francisco by bus. Estimated Cost: \$14.00, including box lunch and guidebook. Trip leader will be Cole R. McClure, Jr. , of the Bechtel Corporation.

Side Trip No. 2: Continue from Oakland by pleasure boat to Sausalito and visit the USED Bay Model. Return to San Francisco by boat, then by bus to the hotel. Estimated Cost: \$10.00, including box lunch and guidebook.

The flying trips will be via Pacific Airline's high-wing F-27 turbo-prop planes. Therefore, these trips will be limited to 44 persons. The Bay pleasure boat accommodates 150 persons, and will be attractive for members bringing their wives and/or families. All reservations will be on a first come, first served basis. Please detach and return the reply coupon below.

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Mr. Elmer Marliave, 4466 N. Park Drive , Sacramento,  
California 95821. (916) 489-4516.

(definitely planning on

I am ( attending one or more field  
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trips, as marked below: NAME.....

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# ENGINEERING GEOLOGY FOR DAMS

W. Harold Stuart

## Exploratory Techniques Employed at Snettisham Dam Site

-- contributed by N. A. Dixon --

A wide range of exploratory techniques ranging from underwater TV cameras to NX bore-hole photography have been employed at the Snettisham damsite to help solve a variety of unique engineering geology problems peculiar to this project.

Project Description. Snettisham dam will be a major feature of the Snettisham hydroelectric development located near the mouth of the Speel River some 28 air miles southeast of Juneau, Alaska. (See photographs on pages 3 and 4.) This project will provide power to the city of Juneau and to future industrial development in the area. The dam will consist of a concrete gravity structure approximately 100 feet in height to raise the level of an existing glacial lake. Water will then be dropped a total of 900 feet through power tunnel and penstock driven in rock to a powerhouse at sea level.

Geographic Setting. The project lies in a very rugged and unpopulated region and is accessible only by boat or float plane. Mobilization on site of all drilling equipment and other supplies was by the use of helicopter transport. The climate,

being typical of southeastern Alaska, is characterized by cool summers and heavy precipitation mostly in the form of rain, which averages approximately 142 inches annually. Forest cover with accompanying dense undergrowth extends from sea level to an elevation of approximately 2,000 feet.

## C O N T E N T S

Field Trips -- GSA	Front
Annual Meeting . . . .	Cover
Engineering Geology	
for Dams. . . . .	1
Geology in Underground	
Workings . . . . .	6
Building Construction	
and Land Development	8
Instrumentation for	
Engineering Geology	12
Rock Mechanics in	
the United States . . .	14
Holdredge Award . . .	16
Conferences and	
Activities of Societies	17
Education. . . . .	18
Activities of Engineering	
Geologists. . . . .	19
New Books and	Back
Upcoming Conferences	Cover

Regional and Project Geology. Many major streams in southeastern Alaska have active glaciers at their headwaters. Their courses from these points of origin to the sea are therefore usually well marked by such typical glacier erosional features as U-shaped valleys, cirque lakes, hanging tributary valleys and morainal sedimentary deposits. Most of the glacial features have been shown to play an important role in providing a general setting for the Snettisham project site geology.

The country rock consists of rock units derived from and associated with the Coast Range batholith.

Specific rock types of this general origin are  
1

quartz diorite and gneiss with minor schist inclusions. The project site is also cut by several major fault zones.

Engineering Geology Problems. The diversion scheme planned for lowering the existing lake in order to construct dam and intake works will be performed by a method of "lake tapping" perfected by Norwegian engineers. A tunnel will be driven in rock from a downstream point some 120 feet below present lake surface. NX guide holes will in all cases be drilled in advance of the tunnel heading as a precautionary measure. Upon reaching a point in the tunnel approximately 20 feet or less from the rock lined lake bottom, a pit is blasted out from the tunnel floor. This pit is pre-sized to receive the last 20 feet of blasted rock carried in by the water surge at the time the final heavy shot for actual breaching or lake tapping is made. In preparing for such a precise engineering feat, it is obvious that a good deal of advanced planning and exploratory investigation is essential if the overall operation is to be a complete success. Important among such needed pre-determinations are the quality of bedrock along the proposed diversion tunnel alignment, true nature of the lake bottom materials in the area to be tapped, and the bedrock and overburden contours beneath the lake.

Another engineering geology study of considerable importance was the investigation of dam site foundations. Inasmuch as Snettisham dam will be constructed upon a partial ridge of granitic rock, all natural rock joints in this ridge foundation were subjected to close scrutiny. Of particular interest were any low angled joints suspected of passing through the foundation ridge thereby forming possible planes of weakness. Features that were investigated in connection with rock jointing were structural attitude, continuity, width of openings, nature of filling materials when present, relief on joint surfaces, cohesion if any, and permeability.

In addition to the foregoing problems which are somewhat unique in character, the Snettisham project also possessed the standard engineering geology problems common to many other hydroelectric development schemes. These may be briefly mentioned as including the location, testing, and proving up of construction materials; appraising the grouting and drainage characteristics of dam and powerhouse foundations; studies of potential reservoir basins for water tightness and potential land slides; and estimating difficulties and contingencies involved in driving tunnels and penstocks through various rock types.

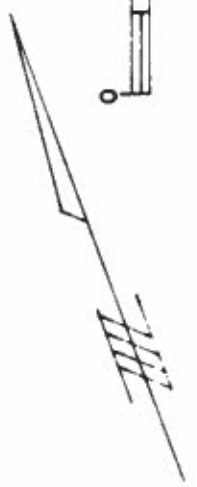
Exploratory Techniques Utilized. As a first step in geologic investigations, the total project area was studied by both colored and black and white aerial photographs using stereographic techniques. It was found that in an area like Snettisham project where much bedrock is exposed, colored aerial photos are able to disclose much more of the minute details of rock cleavage characteristics. By this general method most all major faults and prominent joints systems were mapped in a preliminary way. A follow up field party then made a more detailed geologic study in those specific areas where major project structures were to be located. Drilling, testing and survey programs were then laid out



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# SNETTISHAM PROJECT



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U.S. Army Corps of Engineers

utilizing as a close guide the background knowledge already developed by photo geology and field mapping studies.

Lake bottom topography was first determined by fathometer surveys and later checked for accuracy in all critical areas by leadline soundings through the ice in early spring and from open boat in the summer months. Traverses of the lake bottom were then made utilizing a special underwater TV camera and a SCUBA diver-geologist team from the Scripps Institute of Oceanography.



SNETTISHAM PROJECT --- LONG LAKE DAM SITE  
Scuba Diver-Geologist Team Preparing For Dive  
Traverse of Long Lake Bottom

U. S. Army Photo

These special exploratory techniques revealed the specific location of underwater bedrock outcrops, the general character of the lake bottom sediments, and the heretofore unknown existence of extensive waterlogged tree debris. This pre-knowledge of lake bottom conditions thus enabled preliminary sitings to be made of dam axis, lake tap diversion point, and power intake gate. As a result, barge drilling operations which followed the underwater surveys were able to concentrate in specific areas of interest thereby greatly reducing the amount of actual lake drilling required

In addition to firming up studies required for advanced design of diversion and intake works, the underwater investigations also developed important information on the bedrock characteristics in the upstream portion of the dam site. These features are now concealed from view by the present lake. Among the features of greatest interest were the degree of drop-off to the bedrock surface to better define the damsite ridge and the heretofore mentioned jointing, faulting, or other rock cleavage patterns in this portion of the dam foundation. Much additional correlative information on the bedrock jointing was then obtained from surface studies by geologic mapping, NX and six-inch drilling, extensive borehole photography, and hydraulic pressure testing in overlapping 10-foot intervals in the drill holes. From all of these data a relatively clear picture of the important subsurface geological features began to emerge.

As a further aid to better understanding and for visual demonstration of the three-dimensional aspects of the dam and diversion works, three models were constructed. Two of the models consisted of a series of glass plates (1" = 20' natural scale) showing all of the known subsurface geology and topography beneath the lake and damsite. The other was a topographic model (1/240 natural size) which more clearly demonstrates the relief and ridge character of the overall damsite.

Use Made Of Data. The assimilation, integration, and application of all foregoing exploratory work involved the joint efforts of several engineering geologists and civil engineers. The data obtained from these studies are being used as the basis for design of the dam foundation, lake tap and tunnel support and linings.

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Ice-Bonded Dam Proposed  
-- contributed by George Roberts --

A dam of moderate height is needed for a hydroelectric installation in the Arctic. The site is "beyond the tree line", "beyond the extent of the usual facilities for the transportation of supplies", and in the mountains inland from the beach. No roads or habitation are present in the area.

One of the schemes recommended is: A post-tensioned rubble masonry dam utilizing ice as a bonding agent in lieu of the conventional mortar. Such a scheme would require surface refrigeration during a portion of the year.

Among the factors contributing to the attractiveness of this scheme are the fairly short frost-free construction season, the presence of a glacier above the head of the lake, local availability of labor during the winter months, and the avoidance of importing cement, sand, and heavy crushing and batching equipment.



## GEOLOGY IN UNDERGROUND WORKINGS

Lloyd Underwood

### Carley V. Porter Tunnel, California

Mr. A. B. Arnold of the California Department of Water Resources reports as follows:

"The Carley V. Porter Tunnel, presently under construction in the Tehachapi Mountains in Southern California, is an important feature of the California Aqueduct. The tunnel, 4.8 miles in length and 20 feet in diameter, will traverse from northwest to southeast the following geologic units: highly fractured to crushed, igneous and metamorphic rocks of the Garlock fault zone; deeply weathered to altered Tejon Lookout granites; and slightly indurated siltstones, claystones, and gravelly mudstones comprising lakebed deposits of Pliocene age.

The low bid on the tunnel was \$33,788,800, submitted as a joint venture by Dravo Corporation, Guy F. Atkinson, and S. J. Groves & Sons Company. The contractor has elected to use a shield method of construction working from both portals. Progress to date consists of portal excavation, fabrication and assembly of the shield, and construction of rail and access roads. The shield consists of a steel ring 17 feet long and 20 feet in diameter tapered to a cutting edge. Twenty-four hydraulic jacks built into a center ring of the shield will move it forward by thrusting on the sides of the tunnel. The top half of the shield contains nine forepoling segments that can be individually jacked ahead of the main shield for eight feet. A two-foot-wide liner plate will be welded to steel ribs inside the shield. Pea gravel will be placed behind the liner plate as tunneling progresses. It is expected that the contractor will place the concrete lining on completion of the tunneling operation.

The contractor will "turn under" in March on the south portal and sometime in May on the north portal. Approximately 13 per cent of the time on this contract has been spent on mobilization."

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### Tunneling Prospects in the Northeast Corridor of the United States

Following is the synopsis of a preprint of a paper by Ronald C. Hirschfeld, Associate Professor of Civil Engineering, Massachusetts Institute of Technology, titled, "Possible Use of Tunnels for High-Speed Transportation in the Northeast Corridor":

Underground construction is receiving serious consideration in the study of high-speed ground transportation systems for the Northeast Corridor. Particularly in heavily built-up areas, underground construction avoids many of the problems associated with surface construction, such as high right-



of-way cost, restrictions on route location, interference with existing surface structures or facilities, and aesthetic obtrusiveness. It is, however, more expensive at the present time. The rapid increase of costs for surface construction (primarily because of increasing right-of-way costs), combined with potential improvements in tunnel excavation, makes it reasonable to evaluate the feasibility of constructing underground transportation systems sometime in the future.

The design and construction of underground transportation lines would depend to a considerable extent on geologic factors, of which the most important are: topography, surficial sediments, depth to bedrock, type of bedrock (including rock defects), ground water, state of stress in the earth's crust, geothermal gradient, and fault activity.

A preliminary study of geological conditions indicates that tunnel construction by the cut-and-cover method would be practical only in a limited portion of the Northeast Corridor where the topography is relatively flat and where the land surface is not extensively developed. Slightly deeper tunnels would involve considerable soft-ground tunneling, which is expensive and difficult and which might interfere with building foundations and underground utilities in the cities.

It is concluded that a relatively deep tunnel in bedrock may be the most feasible choice for underground lines, because it avoids most of the problems associated with shallow tunnels, especially in the cities where the advantages of tunnels over surface lines are potentially greatest. To be in sound bedrock, tunnels might have to be constructed at depths of the order of 400 to 500 feet where there are deep bedrock valleys, thick glacial, fluvioglacial or glaciolacustrine deposits, thick Coastal Plain deposits or thick surface zones of weathered rock. Obviously, this depth would vary from place to place within the Northeast Corridor. It is not unlikely that a high-speed ground transportation system might comprise both surface and underground sections, in which case transitions between surface lines and deep tunnels would have to pass through materials at shallow and intermediate depths.

A significant problem associated with making feasibility studies for all tunnels, and particularly long-distance underground transportation lines, is the lack of sufficiently complete geologic information to make reliable estimates of cost and speed of construction.

The potential impact of tunneling machines on the cost and speed of construction of hard-rock tunnels has been studied. Although hard-rock tunneling machines have been used on only about 20 civil engineering projects since the early 1950's, and usually under relatively favorable conditions, they have been improved tremendously in the past 15 years and there is every indication that they will greatly reduce the cost and increase the speed of hard-rock tunneling in the future.

## BUILDING CONSTRUCTION AND LAND DEVELOPMENT

Gary Melickian

### Shallow Land Subsidence in Kern County, California

Certain types of alluvial fan deposits are moisture sensitive, that is, they will settle fairly rapidly under their own weight when they are saturated. The result is an uneven, hummocky topography.

In the last few years, there has been a large volume of data published in the literature on the shallow land subsidence problems studied by the State of California Department of Water Resources in connection with the planning, design, and construction of the aqueduct system through the San Joaquin Valley. The emphasis has been on water distribution systems, and very little has been written on shallow land subsidence beneath airfields, commercial buildings, houses, and so forth.

The initial encounters with subsidence in the San Joaquin Valley were in connection with farming activities in virgin areas. Shallow subsidence has been affecting structures in Kern County since the 1920's. Examples are apparent on the U. S. Geological Survey "Pentland Quadrangle" surveyed in 1930-1931. In the 1930's, settlement of up to 18 feet was reported where water collected behind railway embankments, leaked from pumping stations, or was ponded as waste water from oil wells.

Gardner Field, Kern County, experienced shallow subsidence between 1941 and 1943. Portions of the field settled which had been developed with buildings and structures. The extensive paved portion of the airfield suffered no distress. Elevation control was not good, but as much as four feet of subsidence may have occurred.

In 1949, an investigation for a two-storey office building was conducted in Taft, California. The building was to be located on a nearly flat portion of an alluvial fan. During the investigation, performed by drilling 40-foot-deep borings using rotary bucket-type equipment, it was recognized that the soils had a "honeycombed structure which would lose strength and increase in compressibility when the soil particles were lubricated by infiltrating water". Samples were obtained and subjected to shear tests, consolidation tests, grain-size analyses, and moisture and density determination in the laboratory to confirm the field examination.

Shear tests were run on samples at field moisture and at artificially increased moisture contents. In all cases except one, the shear strength reduced from 50 to 80 per cent upon being saturated, with the same surcharge pressure being applied in both cases.

The result of a consolidation test is shown in Figure 1 (below). Thirteen per cent consolidation occurred upon saturation.

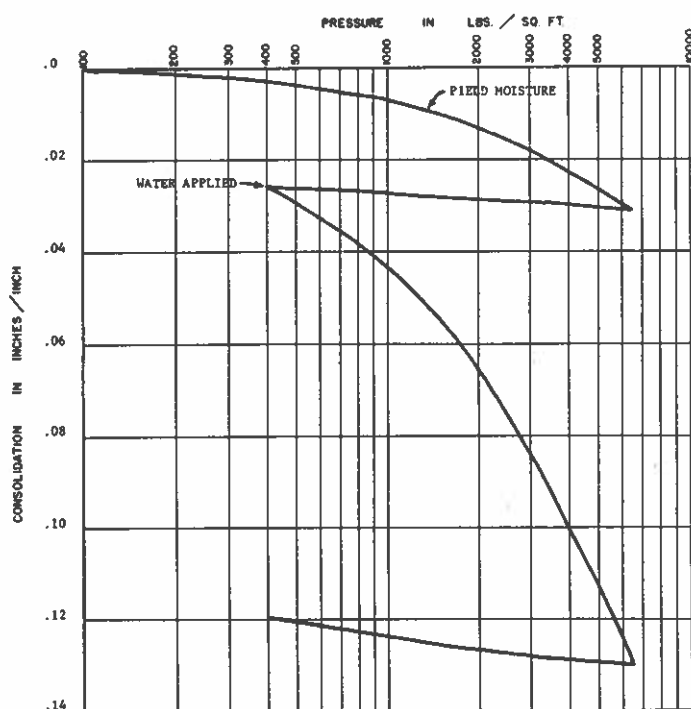


Fig 1. Consolidation Test Data

It was felt that spread footing for support of the structure was not feasible, since it could not be assured that the soils underlying the site would not increase in moisture content. It was recommended that drilled cast-in-place concrete piles would be more economical and more desirable than taking protective measures against moisture infiltration. The pile capacities were computed using skin-frictional resistance based on the shear test data. The values selected were conservative. The capacities assumed that the uppermost ten feet of the soil might become wet and actually impose a downward load on the piling rather than offer support.

At the time the investigation took place (1949), drilled piles were an unusual recommendation for such a light structure. However, earlier experiences at Gardner Field and elsewhere led the engineers to suspect that certain alluvial fan soils would subside or settle substantially upon saturation. Testing confirmed this suspicion. However, at that time, it was not realized that water from lawns would percolate to 60 or so feet.

In June of 1952, the owner became concerned when substantial settlement was observed at one corner of the building. The owner drilled borings to depths of 30 feet. Moisture data obtained at that time were compared with moisture data obtained in 1949. At the corner of the building undergoing settlement, the moisture content for the first 30 feet was similar to the moisture content during the initial investigation. It was difficult to explain why settlement would be occurring at this corner when the moisture content had not been appreciably changed. However, no information was available regarding changes in moisture content at greater depths, since drilling had extended to only 40 feet and 30 feet for the 1949 and 1952 investigations respectively.

When the original foundation investigation was made, it was assumed that the moisture would be confined to relatively shallow depths. However, the soils were sufficiently porous to allow water to percolate deeper, and yet sufficiently fine grained to retain the moisture.

The possible causes of moisture infiltration were studied. It was felt that the sources were prolonged irrigation of the adjacent lawns, improper drainage along an adjacent road with concentration of water along fill embankments, and leaks in water lines beneath the road and between the buildings.

Sinks were filled in and planting immediately west of the new building was removed. Also, areas were backfilled with impervious clay material to prevent infiltration of surface drainage. The roadway grading was corrected so that it was crowned at the center, and surface drainage was carried away from the office buildings.

It was felt that considerably more settlement would have occurred if the buildings had not been on drilled caissons. However, it was still necessary for the owner to undertake the releveing of the building. The caissons were cut from the grade beams and attempts were made to jack the building up. Measurements were taken before jacking operations and after jacking operations. The measurements taken after the presumed releveing of the structure indicated that the structure had not moved, although the spacing between the caissons and the grade beams had increased. The caissons were being jacked down rather than the building being jacked up.

Luckily, the rate of settlement was decreasing and eventually ceased. If the problem soils had extended much deeper, settlement might have continued for several more years.

### Housing in Bakersfield

Similar land subsidence is widespread in the Bakersfield area. The problem was first recognized around 1955. There may now be as many as a hundred homes that have been damaged as a result of the moisture-sensitive soils.

A couple of years ago, an investigation was made of a 1000-home tract. About 56 of the 1000 or more homes had been mud jacked. More than 90 per cent of these (affected) homes are in areas where fill soils had been placed over existing ravines. Shallow mud jacking beneath the houses was of little value. In one house, after damage was originally noticed, the structure was releveed by mud jacking. The mud jacking eliminated most of the differential settlement within the house at that time. However, since that time, the house has continued to settle and the structure ended up in worse condition than existed prior to the time of releveing. Some of the homes have been mud jacked at least three times and are still settling.

The source of settlement may be materials which extend to a depth of 50 feet. An extensive underpinning scheme and deep mud jacking might be required to permanently stabilize the structure and the subsoils beneath the houses.



The settlement has been attributed to inadequate stripping in the gullies before filling, poor compaction of the fill material, the inclusion of organic material in the fill, and a surface veneer of windblown material. However, some houses have settled which were constructed on cut as well as fill materials. Below some of the damaged houses, the fill was well compacted.

These deposits are moisture-sensitive alluvial fan materials, firm and hard when dry, but weak and compressible under their own weight when saturated. Some characteristic gradation curves, indicative of mudflow deposition, are shown in Figure 2 (below). With 15 to 25 feet of fill as a surcharge, the formation will settle up to 10 per cent of its volume upon saturation. Under one residence, these soils were found to be 20 feet thick.

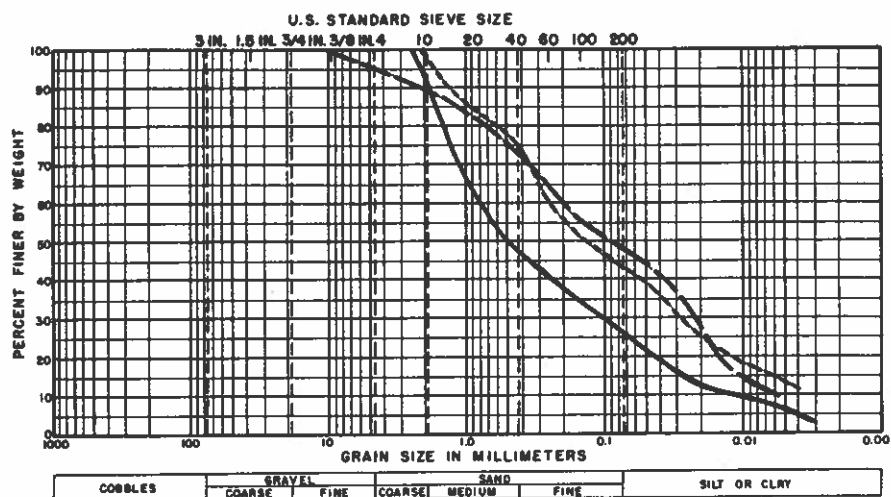


Figure 2. Gradation Curves

Kern County will see a considerable amount of growth in the next couple of decades. If land values are high enough, more intense investigations and expensive corrective measures are warranted. Until then, development may continue without adequate geologic and engineering studies.

Certain measures have proven to be effective, however. Excellent surface drainage and paving of areas around houses seems to reduce the number of problems. Finally, landscaping with desert-type vegetation is recommended. These plants require much less water and moisture infiltration is not nearly as deep.

## INSTRUMENTATION FOR ENGINEERING GEOLOGY

Sig. Schwartz

### Review of Seismic Exploration in Engineering Site Studies

Seismic exploration is the most commonly used of all geophysical techniques for the exploration of engineering sites. The principal engineering uses of seismic exploration are in the development of subsurface information for use in feasibility, site selection or foundation design studies and in the classification of excavation for estimating construction costs. Where properly applied, the seismic method can produce a general subsurface picture of a site quickly and economically and when used in conjunction with test borings will generally produce detailed information that could not otherwise be obtained.

Seismic investigations can be used to greatest advantage in reconnaissance surveys for site selection or feasibility studies where a general understanding of subsurface conditions is required prior to final site selection and detailed investigation for design. Maximum usage is obtained when a reconnaissance seismic investigation is completed prior to preliminary test borings and the results used to eliminate undesirable sites and to select locations at which preliminary borings are to be put down at a selected site. Under these circumstances, a much broader picture of subsurface conditions is obtained in the reconnaissance stage of an investigation and exploratory drilling can be confined to key locations at the selected site thereby reducing the number of borings required. It is also practical to complete preliminary test borings in advance of a seismic survey and to use the geophysical investigation to extend the results of the test borings throughout the site area, although this procedure is usually somewhat less effective because the borings are seldom placed at key locations.

It is appropriate to use seismic information for final design studies only when correlative information is available from other more direct methods of exploration and used to substantiate the seismic results. Under these conditions it is usually possible to attain greater than 90 per cent accuracy if the site is well suited to this method of exploration.

Classification of excavation through the use of seismic data is a frequently used method for estimating construction costs. Seismic velocities below 5,000 feet per second usually indicate earth material that can be easily handled by excavating equipment and velocities above 10,000 feet per second usually indicate earth materials that will require blasting. It is often hazardous to attempt prediction of the excavating characteristics of earth materials having seismic velocities between 5,000 and 10,000 feet per second without carefully considering the nature and origin of the material and the type of construction equipment that will likely be employed. Previous seismic and geologic experience in an area or geologic province is always desirable.

Refraction and reflection seismic methods are both used for subsurface exploration. The refraction seismic method is generally more applicable to engineering investigations although the seismic reflection method can be applied in some instances, particularly for overwater investigations. It is always necessary to have a condition of contrasting seismic velocity between various subsurface strata in order to properly apply either of these methods. In the case of refraction exploration, it is necessary that the strata increase in velocity with depth.

Use of Instruments. Various types of instruments are available for seismic investigation of engineering sites including single or multichannel equipment for land and overwater exploration and continuous reflection profiling equipment for overwater exploration. Single-channel equipment normally employs a dropping weight such as a sledge hammer for a source of seismic energy although some units of this type can be used with small explosive charges. Effective penetration of this type of equipment is generally of the order of 30 feet although penetration of the order of 200 feet is possible under ideal circumstances. Equipment of this type is generally more suitable for obtaining point information rather than for surveying large areas or making detailed investigations of a proposed site.

Multichannel seismic instruments usually employ an explosive charge as a source of seismic energy but can also be used with weight dropping or hammer blow techniques similar to those used with the single-channel instruments. Depth of penetration obtained with this type of equipment is not limited as with the single-channel equipment and penetration depths of 1,000 feet or more are practical. Data produced by multichannel equipment can be interpreted in more detail if proper field techniques are employed and are therefore more suited for detailed investigations of engineering sites. This is particularly true when relatively large areas are involved and penetrations of more than 30 feet are required. Multichannel equipment can be adapted for overwater work by using an array of hydrophones rather than geophones as seismic detectors.

Overwater Reflection Instruments. Considerable advances have been made over the past few years in continuous overwater reflection profiling instruments. This type of equipment employs a repeatable energy source consisting of an electrical, electromechanical, pneumatic or explosive gas mixture device. Data produced by these instruments are displayed on a recording chart in much the same way as a fathometer produces a bottom profile. However, in this case, sub-bottom strata are also shown on the chart within the limits of seismic penetration and reflection. This type of equipment is effective only where the acoustic properties of sub-bottom materials are amenable to penetration by, and reflection of, seismic energy. Conditions under which this type of equipment can be employed are generally more limited than where overwater refraction methods can be employed, for two principal reasons. The amount of usable seismic energy produced by repeatable energy sources is less than that produced by explosives and it is not possible to achieve the desired penetration under certain conditions where abnormally high absorption or attenuation of seismic energy occurs. Also, the application of this method under conditions of shallow water and nearly flat-lying substrata is difficult owing to the confusion of sorting out frequent bottom

and sub-bottom multiples from real reflections. However, continuous overwater seismic reflection surveys can produce considerably more information than a refraction survey when this technique can be successfully applied.

The production of seismic data by any of these methods is a relatively simple matter, although proper field techniques and interpretation of data to produce the maximum usable information in a specific geologic environment is not a simple matter and requires considerable forethought and experience. Optimum results are obtained when proper instrumentation is employed for a specific project by personnel experienced in a variety of field techniques and methods of data interpretation.

It is most important that personnel responsible for the field work as well as the interpretation of the data are well oriented in both geology and geophysics and have a sufficient knowledge of engineering to understand the engineering significance of their findings.

## ROCK MECHANICS IN THE UNITED STATES AS OF JANUARY 1, 1966

William R. Judd

Today's status of rock mechanics in the United States is difficult to evaluate because of the lack of a nationally accepted definition of what is meant by rock mechanics. In the fall of 1963, the National Academy of Sciences --- National Research Council Committee on Rock Mechanics attempted to resolve this problem by formulating the following definition:

Rock Mechanics is the theoretical and applied science of the mechanical behavior of rocks; it is that branch of mechanics concerned with the response of rock to the force fields of its physical environment.

This definition then was used as the basis for the Committee's 1964-1965 survey of rock mechanics research in the United States (that, for good measure, included some of the work in Canada)\*. Replies from 344 academic departments indicated considerable variance in the meaning of the phrase 'rock mechanics'. For example, the survey showed that 66 textbooks, ranging from electronics to matrix analysis with a heavy emphasis on elasticity, mining, and structural geology, were being used to teach 'rock mechanics'.

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\* These data are obtained from "Rock Mechanics Research in the United States 1965 (including a partial survey of Canadian universities)" by the Committee on Rock Mechanics, National Academy of Sciences -- National Research Council, Division of Earth Sciences, Washington, D. C. (to be published 1966).



A fairly clear picture of the current status of rock mechanics in the universities did result however. 136 departments have a partial course, and complete courses at graduate or undergraduate level were offered in 31 mining engineering departments, 15 geology and geophysics departments, four civil engineering and two petroleum engineering departments. University research in rock mechanics heavily emphasizes laboratory measurement of rock properties and applications related to underground openings; there was considerably less emphasis on field measurements, structural geology, and investigation into the state of stress in the earth's crust, and only limited work on comminution, subsidence, surface foundations, excavations, and rock as a construction material. (The survey document, in addition to the numerical findings, also lists all graduate theses from 1931 to 1965 that are related to rock mechanics.)

The committee's survey of industry elicited 139 responses that indicated 35 per cent of the respondents were engaged in active research in rock mechanics; of this group, 40 per cent were mining, 37 per cent consulting and contracting, 27 per cent manufacturing, and 17 per cent were petroleum companies. One favorable finding was that from 1963 to 1965, industry's reported expenditures for research increased by 50 per cent with the consulting and contracting industry spending more than the other groups. Furthermore, almost 20 per cent of industry also supports research as a "non-commercial" venture, such as grants to universities and scholarships. Industrial research in rock mechanics appears to have gaps somewhat similar to those found in academic research: there appears to be little industrial research on the rock mechanics problems involved in surface excavations and foundations, rock as a construction material, and structural geology; and their research on fundamentals is concentrated on stress, strain, and failure theory with little being done on the state of stress in the earth's crust.

The third part of the survey investigated the activities of ten federal agencies known to be engaged in rock mechanics research. In 1965, these agencies spent about \$7 million on 186 projects directly related to rock mechanics. It is also known there are a number of other federal projects in rock mechanics that could not be identified because of national security regulations. About 30 per cent of the total expenditure was for contract research. Federal research appeared to have a relatively good distribution of effort between fundamentals, measurements, and applications. However, there was only nominal research on rock as a construction material and on comminution.

The increasing stature of rock mechanics today is also indicated by the growing number of identifiable rock mechanics groups in United States professional societies. The following list of such groups is believed to be complete; however, if any reader knows of others, the author of this article would appreciate receiving such information: 1. American Geophysical Union (no specific committee); 2. American Society for Testing and Materials (Subcommittee 12, "Subcommittee on Rock Mechanics", of Committee D-18); 3. American Institute of Mining and Metallurgical Engineers (Ad Hoc Committee on Rock Mechanics); 4. Association of Engineering Geologists (no specific committee); 5. Geological Society of America (Committee on Rock Mechanics);

6. Highway Research Board (Committee on Soil and Rock Properties); 7. Inter-society Committee on Rock Mechanics (composed of representatives from each of the organizations listed here); 8. National Academy of Sciences - National Research Council (U. S. National Committee on Rock Mechanics); 9. Seismological Society of America (no specific committee); 10. Society of Exploration Geophysicists (no specific committee); 11. Society of Mining Engineers (Committee on Rock Mechanics in the Exploration and Mining Division) - (Committee on Rock Mechanics in the Coal Division); 12. Society of Petroleum Engineers (no specific committee).

The National Academy of Sciences Committee on Rock Mechanics organized the Intersociety Committee as a group to co-ordinate (and, hopefully, to reduce) the increasing number of U. S. symposia on rock mechanics. This Intersociety Committee still is in the throes of organization but at their next meeting (September 1966) probably will adopt clear-cut objectives in regard to an annual interdisciplinary symposium.

In summation, rock mechanics in the United States has reached significant national stature. With the relatively recent adherence of the U. S. National Committee on Rock Mechanics to the International Society for Rock Mechanics its international status also is recognized. The rapid growth of rock mechanics within the last very few years clearly indicates that this field is of concern to many scientific and engineering disciplines. Therefore, significant future progress in solving an increasing number of problems in rock mechanics will require increasing use of interdisciplinary methods. And, of most value, from an interdisciplinary approach, will be an increasing interaction between the sciences of geology and mechanics.

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#### PROFESSOR KIERSCH RECEIVES CLAIRE P. HOLDREDGE AWARD

George A. Kiersch, a past-chairman of the Division and Professor of Engineering Geology and Chairman of the Department of Geological Sciences at Cornell University, was recently designated the first recipient of the Claire P. Holdredge Award by the Association of Engineering Geologists. This award was established to honor authors of technical publications in engineering geology that are judged to be significant contributions to the advancement of the profession. The award was given for his two papers on the "Vaiont Reservoir Disaster" of 1964 and 1965. He is the author of some 50 papers in engineering geology over the past 15 years based on his serving as a consultant to many corporations and government agencies throughout the United States and at foreign sites.

## CONFERENCES AND ACTIVITIES OF SOCIETIES

R. E. Goodman

### Fourth Annual Symposium on Engineering Geology and Soils Engineering Contributed by J. W. Peebles and George A. Williams

The Fourth Annual Symposium on Engineering Geology and Soils Engineering was held April 19, 20 and 21, in the Student Union Building of the University of Idaho at Moscow. Over 150 registered for the meeting including engineers and geologists from 16 states, 2 Canadian provinces, and the District of Columbia.

The program included outstanding papers in a wide range of subjects covering engineering materials, foundation studies, hydrogeology, soil mechanics, and rock mechanics.

In the session on rock mechanics, A. L. O'Neill of the California Department of Water Resources discussed techniques for rock reinforcement in underground construction using rock bolts and E. C. Chandler of the U. S. Army Corps of Engineers described the solution of an uplift problem at Little Goose Lock and Dam on the Snake River resulting from artesian water pressure.

Foundation studies involved a summary of recent information on the failure of the Peace River highway bridge by Dean R. M. Hardy of the University of Alberta, an analysis of a bridge foundation supported by batter piles by Professor L. C. Reese of the University of Texas, and a discussion of the application of the Rankine earth pressure theory by Dr. G. L. Martin of Montana State University.

Dr. W. N. Laval of Lewis-Clark Normal School discussed the engineering geology of tertiary formations and structures in south-central Washington, R. H. Fryxell of Washington State University described the distribution, origins, and geologic characteristics of loess, and P. A. Domenico of the University of Nevada presented a paper on geologic controls and measurements on land subsidence in Las Vegas Valley.

Field investigation techniques for highway design purposes were described by D. J. Kremer of Rader and Associates, a discussion of the use of surcharges to minimize post-construction settlement of highway fills was made by W. F. Kleiman of the California Division of Highways, and research activities in geological engineering at the University of California at Berkeley were summarized by Dr. R. E. Goodman.

The session on hydrogeology included a paper on sediment control for large unlined canals by Leonard Rice of Tipton and Kalmbach, Inc., a description of seepage controls and observations at Garrison Dam by H. A. Sikso of the Corps of Engineers, a discussion of permeable materials for engineering

drainage by H. R. Cedergren of the California Department of Water Resources, a paper concerning the role of the engineering geologist in ground-water basin management by L. C. Fowler of the Santa Clara County Flood Control and Water District, a summary of ground water research in the Pullman-Moscow basin by J. W. Crosby of Washington State University and a study of ground-water movement in landslides by W. V. Jones of the University of Idaho.

The use of nuclear explosives in civil construction was described by Dr. S. M. Hansen of the University of California, the current status of nuclear testing for moisture and density of soils and related materials was summarized by W. G. Gunderman of the Highway Research Board, and scale-model evaluation of earthmoving tools was presented by J. D. Gentry of the Caterpillar Tractor Company.

In the final session, V. R. Chaves of the Bureau of Public Roads, described the use of color aerial photography in engineering materials surveys, T. R. Howard of the University of Idaho discussed investigation of test methods to determine basalt aggregate breakdown, and Dr. E. Y. Huang of Michigan Technological University described moisture-density relations of soil-aggregate mixtures as affected by the geometric characteristics and gradation of coarse aggregates.

At the banquet, Dr. E. F. Cook of Texas A & M University gave a penetrating talk concerning the need for social scientists to cope with problems arising from our expanding technological society.

The symposia are co-sponsored by the Idaho Department of Highways, the College of Engineering and Department of Geology and Geography of the University of Idaho, and the Department of Geology of Idaho State University.

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## EDUCATION

Engineering Geology at Cornell University. Dr. Shailer S. Philbrick, well-known engineering geologist, with 30 years' experience with the U. S. Corps of Engineers, joins the Department on July 1, 1966 as Professor of Geological Sciences. Dr. Philbrick will assist Dr. Kiersch in offering four advanced-level courses in Engineering Geology in Cornell's graduate program in Engineering Geology. Along with the inter-disciplinary courses offered by co-operating faculty in the Colleges of Engineering, Agriculture, Architecture, and the Arts College, Cornell has a big program. Next fall, there will be one postdoctoral student, three Ph. D. and one M. S. candidates in Engineering Geology, which is about the limit for graduate students as the total Department is limited to 14 students. All of the students take two minors outside the department with one of the co-operating faculties.



## ACTIVITIES OF ENGINEERING GEOLOGISTS

Arthur Cleaves

George A. Kiersch, Professor of Geology at Cornell University, writes:

Since April 1965, I have been involved with the geologic investigations of leakage, assessment of the causes, design of remedial treatment, and two separate grouting programs on Golder Dam, a 140-foot high, earthfill dam near Tucson, Arizona. Completed in 1964 with a minimum of geologic studies before construction, the first reservoir impoundment in July 1964 resulted in immediate leakage and a sizeable loss through underseepage below the core trench. The systematic geologic investigations begun in April 1965, located the causes for the loss, and the first grouting program began in July 1965 to seal off defects within the earthfill embankment and core trench. Since completing this phase, the second stage, pressure grouting of pervious sand and gravels beneath the dam, has progressed satisfactorily and today the underseepage and through flow has been reduced to less than half of the original losses. Grouting will continue until a satisfactory seal has been completed. Both cement slurries and chemical mixtures have been used in sealing off the sands and gravels beneath the core trench.

A second project has been the site investigations for a nuclear reactor for the Puerto Rico Water Resources Authority, near San Juan, Puerto Rico. The need for locating the site near to the ocean, has placed the plant in a geologic environment having the greatest number of potential problems.

Frank C. Sturges, President, Penna. Drilling Co., in Pittsburgh, is the only head of a major drilling company that I know of who was a geology major in college. He took over this company when his father retired. He is also a Fellow, GSA.

Penna. Drilling Co. does all the conventional types of drilling -- diamond, auger (large diameter etc.) and calyx; but perhaps is best known to some of us for specializing in large diameter borings. For example -- their calyx holes at the "Underground Pentagon" (not the true name) were 600 feet deep and 36 inches in diameter and were drilled through "greenstone" loaded with epidote. I went down one of these holes and it was some experience! Larger diameter holes have been drilled by Penna. Drilling for mine shafts.

When the Corps of Engineers' "bore-hole camera" came out, Frank was not far behind. They have developed bore-hole cameras for use in six-inch and eight-inch holes that might be considered large diameter because they are larger than the conventional NX. These stereo cameras can be rigged for underwater shots where the head is up to 8,000 feet. I have some of Frank's photos taken with his horizontal camera through an eight-inch hole drilled into an old abandoned mine. Here, in places where there wouldn't be any core anyway, the photographs are amazing. Of course the camera can be rotated so one can have shots along any azimuth.

"Imagine, if you will", Frank writes, "having enlargements, in color if desired, in a warm dry office with a cup of coffee at your elbow instead of hours of swinging in a hole with cold water running up your sleeve and down your nose, spattering your glasses and notes."

William R. Judd, formerly with the Rand Corporation, Santa Monica, is now a Professor, no less, at Purdue University, Lafayette, Indiana 47907. Joint appointment in Civil Engineering and Geology (Rock Mechanics, Soil Mechanics and Geology) Will develop a graduate program.

Chester Lucas, our Rome correspondent and President of McGaughy, Marshall, McMillan and Lucas, is responsible for the design of the new city of El Marj, about four miles from Barce in Libya. There is no through traffic, which has to circle the city. Electric lines are buried, gas and water mains are flexible, and the building construction (low structures) is such that the 7,500 homes may flex with the rolling motion of an earthquake. The homes are spaced well apart and combine architectural features incorporating modern western and local Libyan concepts and desires. The water supply comes from deep wells.

Mr. Lucas, a Civil Engineer, is a geologically minded engineer, and this writer (Cleaves) enjoyed considerable correspondence with him during the planning stages of the project relative to street and building orientation in relationship to the joint and fracture system, and the utilization of thick overburden areas for parks and playgrounds.

In February 1963 a devastating earthquake levelled much of Barce killing 300 persons and making thousands homeless.

Barce was the capital of Cyrenaica in 221 BC?, the home of Berenice, a princess of Cyrene, who married Ptolemy III of Egypt in 247 BC. The city was located in a dip-slope valley, about 11 miles inland from the sea, some 60 miles east of Benghazi (of Rommel and World War II fame).

The escarpment on the sea side is about 1 1/2 miles inland and the strata dip gently toward the southeast. A second escarpment is about two miles southeast of Barce.

The new city is on higher ground where the soil overburden is much thinner. Professor J. Kazuo Minami of Waseda University in Japan, who is a structural engineer specializing in antiseismic construction and soils and foundation problems, prepared the earth sciences data, first at the request of UNESCO and subsequently for the Barce Reconstruction Authority. He had the advice of local geologists. Dr. Minami is Secretary-General of the International Association of Earthquake Engineering.

The new site area is on land previously owned by the Libyan government

## NEW BOOKS AND LITERATURE IN ENGINEERING GEOLOGY

Raymond Whitla

Hartmann, Burt E. , **ROCK MECHANICS INSTRUMENTATION FOR TUNNELS:** Terrametrics, Inc. , 10805 West 44th Avenue, Wheat Ridge, Colorado, 153 p. , 1966, price \$4. 00 (paper bound). This book was written in an attempt to clarify the present "state of the art" in tunnel construction and to show how modern engineering geology and rock mechanics techniques may be used to obtain more precise design and to control construction costs. After discussing tunnel engineering considerations, the book describes the various types of measurements and information that should be obtained and describes various instrumentation systems. It winds up with a discussion of the application of the data obtained and presents a suggested specification for a rock mechanics program for inclusion in a tunnel construction contract.

Dutro, Howard B. , **ROCK MECHANICS STUDY DETERMINES DESIGN OF TUNNEL SUPPORTS AND LINING:** Civil Engineering, v. 36, no. 2, p. 60-62, Feb. 1966. The author of this article is a rock mechanics field engineer for Terrametrics, Inc. In the article, he describes the rock mechanics instrumentation program that was carried out during construction of twin highway tunnels on Interstate Highway 80 near Green River, Wyoming, to determine tunnel support requirements. The tunnels are each about 1,100 feet long and are bored through nearly horizontal beds of marlstone, siltstone, sandstone, and shale of the Green River formation. The author takes up about half the article in a brief review of the general principles of load redistribution in rock as an opening is excavated into it and in discussing general support considerations before discussing the instrumentation program at this particular project.

**THE HYDRAULICS OF WATER WELLS:** The Johnson Drillers Journal, v. 37, no. 4, p. 1-3, 13, July-Aug. 1965; no. 5, p. 6-7, 12-13, Sept. -Oct. 1965; no. 6, p. 2-5, Nov. -Dec. 1965; v. 38, no. 1, p. 8-10, Jan. -Feb. 1966. This series of articles was written with the idea in mind that the hydraulics of wells should be understood sufficiently by both the men who design the wells and those who drill them for these men to be able to visualize what occurs in a well and in the aquifer when the well is pumped. The articles describe the manner in which water flows through water-bearing formations and into a well and discuss the forces governing its behavior making as little use of mathematics as possible. The journal in which the articles appear is published by Edward E. Johnson, Inc. , St. Paul, Minnesota.

Lattman, Laurence, and Ray, Richard C. , **AERIAL PHOTOGRAPHS IN FIELD GEOLOGY:** Holt, Rinehart and Winston, Inc. , 383 Madison Avenue, New York, N. Y. 240 p. , 1965, price \$3. 95. This is one of the first in a series of paper back books being published by Holt, Rinehart and Winston covering geologic field techniques. The book is bound in flexible, plastic covers for easy handling in the field. It will be useful to the field geologist as a guide to photogrammetric and photo-interpretation procedures.

## UPCOMING CONFERENCES

### Third Asian Regional Conference on Soil Mechanics and Foundation Engineering.

To be held in Haifa, Israel, September 25-28, 1967. The conference will be divided into six divisions considered to be of particular interest to countries in the Asian Region: (1) Eolian soils - properties and engineering problems (2) Lateritic soils - properties and engineering problems (3) Expansive clays - properties and engineering problems (4) Seepage and infiltration problems (5) Foundations of sea and waterfront structures (6) Miscellaneous problems. For further information, request a copy of Bulletin No. 1 from Dr. G. Kassiff, Secretary, Third Asian Regional Conference, S. M. F. E. Soil Engineering Building, Technion City, Haifa, Israel.

### Third Panamerican Conference on Soil Mechanics and Foundation Engineering.

To be held in Caracas, Venezuela, July 8-17, 1967. Detailed information about the conference and requirements for submitting papers is now available in Bulletin No. 2. The deadline for submitting papers will be December 31, 1966, and the papers, prepared in accordance with the instructions in Bulletin No. 2, and requests for information and for Bulletin No. 2, should be sent to the Secretary of the Organizing Committee: Sr. Secretario, Comité Organizador del III Congreso, Panamericano de Mecánica de Suelos e Ingeniería de Fundaciones, Apartado No. 10760 Sabana Grande, Caracas, Venezuela.

### Fourth Regional Conference for Africa on Soil Mechanics and Foundation Engineering.

To be held in Cape Town, South Africa, December 11-15, 1967. The basic theme of the conference will be "soil forming processes and associated engineering problems" but other aspects of soil mechanics and foundation engineering will be considered. Subjects of specific interest are: (1) Laterites, ferroconcretes, and calcretes (2) Transported soils (3) Residual soils (4) Airphoto interpretation and soil engineering mapping with particular reference to the above topics (5) Miscellaneous subjects including material variability and control techniques. For further details, request Bulletin No. 1 from: The Secretary, 4th Regional Soil Mechanics Conference, P. O. Box 3825, Cape Town, South Africa.

### Association of Engineering Geologists - 1966 National Meeting.

To be held at Disneyland, October 18-23, 1966. For information and meeting agenda write to Mr. Dennis Evans, P. O. Box 4215, Glendale, California 91202.

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## THE ENGINEERING GEOLOGIST

Editor -- Richard E. Goodman  
475 Hearst Mining Building, University of California  
Berkeley, California 94720

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