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The Engineering Geologist

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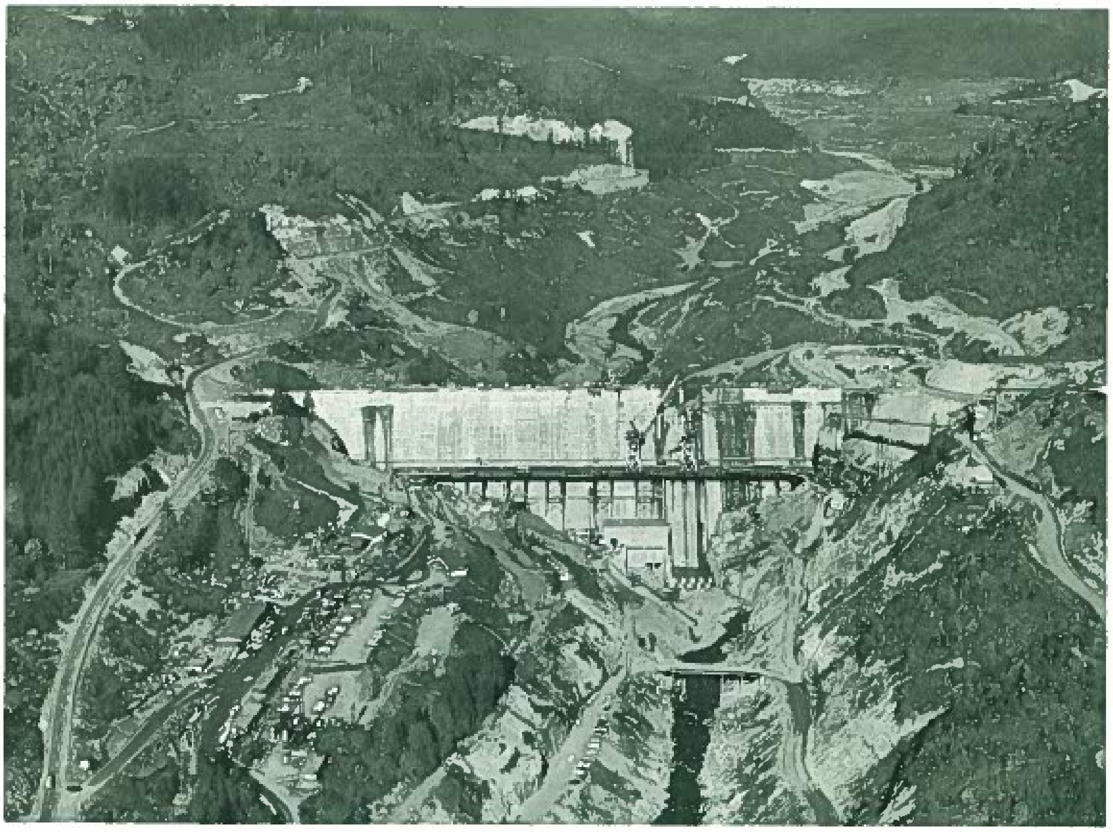

GREEN PETER DAM - MIDDLE SANTIAM RIVER, OREGON
(Photographed 4 October 1966)

ENGINEERING GEOLOGY FOR DAMS

W. Harold Stuart

The Green Peter Dam, a 330-foot-high concrete gravity structure on the Middle Santiam River, Oregon, is nearing completion.

Instruments are being installed in the foundation, in both abutments downstream from the dam, and in the structure to measure foundation movements, uplift pressures, and ground-water conditions.

Deflectometers, extensometers, and optical plummets are installed to measure movements in the foundation of the dam. The deflectometers are installed in vertical core holes and will measure essentially horizontal movements in six vertical zones to depths of 130 feet. The multiple position extensometers are installed in vertical or angle (45°± upstream and downstream) NX core holes. These will measure movements in the order of 0.0001 inch in vertical or horizontal directions or components thereof and can isolate the zone of movement. The targets for the optical plummets are set as much as 130 feet into the foundation and will reveal relative movement between the target and the concrete structure. The plane or zone of movement cannot be determined with the optical plummet.

Uplift pressures will be measured by piezometers at the foundation and at potential zones of uplift in the foundation rock.

Two accelerometers, one near the base and one near the top, are installed to measure accelerations and intensities of earthquake movements.

Piezometers, slope indicators, and deflectometers are being installed in the abutments downstream from the dam to determine ground-water conditions and detect any movement of overburden or rock on these slopes.

The reservoir will be filled this spring, and observations will be made at close intervals during the period of pool raising and periods of fluctuation. An analysis of the effects of the pool on the dam foundation and abutments will be made after sufficient experience and observations are available for valid conclusions to be drawn.

CHOWILLA DAM, SOUTH AUSTRALIA
Contributed by D. H. Stapledon

The proposed Chowilla Dam, construction of which will begin in 1967, will be the largest water-conservation project in South Australia. The dam will be built on the River Murray, 392 miles upstream from its mouth. It will consist mainly of a rolled-earth embankment about 50 feet high and 18,000 feet long. It will also include a concrete spillway section 800 feet long and a navigation lock.

In the early investigation stages, the Engineering Geology team of the Geological Survey determined the stratigraphy of the site area and, during the design stage, has provided geological services to the Engineering Department, the Water Supply Department, and its consultant, Soil Mechanics Ltd. The site presents several unusual geological problems which have greatly influenced the design of the dam.

The site is within the Murray Basin which contains several thousand feet of weak rocks and unconsolidated sediments of Mesozoic to Recent age. In an engineering sense, most of these materials are classified as soils. The geologic succession at the site (Fig. 1) is summarized in Table 1 (opposite).

The dam embankment will consist essentially of an impervious core, supported on both the upstream and downstream sides by thick shoulders of compacted sand (Fig. 2). Selected materials from the Newer Valley Deposits will be used for the core, and Parilla Sands will be used for the shoulders.

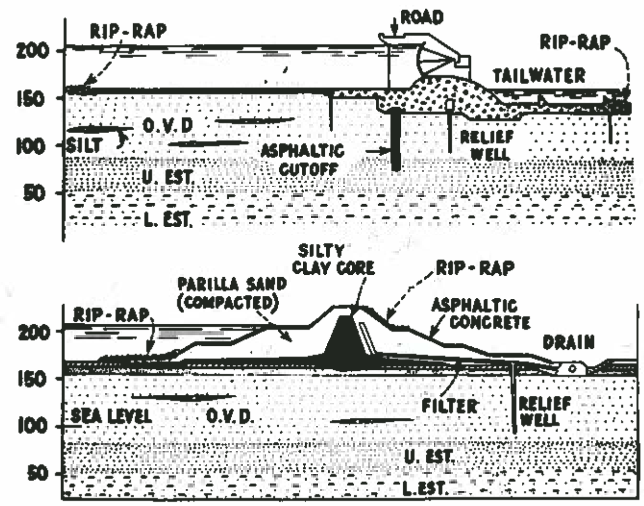

Figure 2. Sections through proposed Chowilla Dam

The embankment will be founded on the Older Valley Deposits which are strong enough to support it but have a very high permeability. The Upper Estuarine Deposits are also highly permeable. To reduce seepage under the embankment to an acceptable figure, an extensive blanket of clay will be placed on the upstream side. In the vicinity of the concrete spillway and lock sections, a partial cut-off wall 80 feet deep will be constructed.

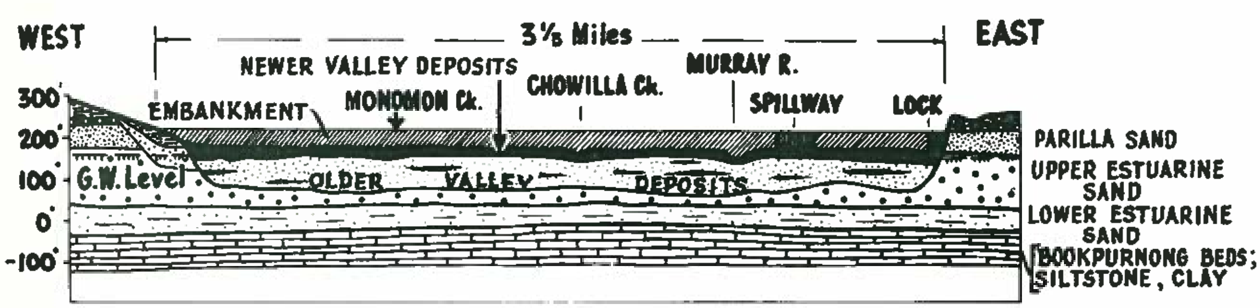

Figure 1. Geological section through Chowilla Dam site

Ground water occurs at shallow depth and is highly saline. Ground water displaced during operation of the dam will be collected in relief wells and drains and pumped to evaporation basins several miles from the site.

The absence of sufficient quantities of durable rock within 100 miles of the dam has led to the adoption of a bituminous concrete facing for protection of most of the slopes. More than a million tons of high-quality rock are still required for riprap and filters, for aggregate in the bituminous membrane, and for the concrete structures. Granite from a quarry site 150 miles away will be transported to the site by rail.

Table 1. Summary of Geologic Succession at the Site

Unit name	Age	Thickness (feet)	Location	Description
Newer Valley Deposits	Recent	0 - 30	Foundation	Silty clay and clayey silt with some fine sands
Older Valley Deposits	Pleistocene	50-100	Foundation	Quartz sands of river origin, medium-and coarse-grained
Parilla Sands	Pliocene	80	Valley sides	Quartz sands, lacustrine origin, medium-grained, clayey
Upper Estuarine Deposits	Pliocene	20 - 60	Foundation	Quartz sands, fine-and coarse-grained, clayey in part
Lower Estuarine Deposits	Upper Miocene	40 - 50	Foundation	Sand, fine-grained, silty and clayey

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A Letter to the Editor

Dear Sir:

In The Engineering Geologist, October 1966, the contribution by E. R. Harrington titled Elephant Butte (page 5) makes good reading as a romantic tale interestingly told. It is a graphic human interest story that enlivens the history of dam construction in western reclamation development.

The story prompted me to dig into old files and turn yellowed pages of Elephant Butte boring records dating back to 1903 which were available to me as Regional Geologist, Region 5, U.S. Bureau of Reclamation. Records included logs of core holes drilled under direction of J. A. French, Engineer-in-Charge, in the early years; also, they included logs of core holes drilled in 1942 in connection with spillway rehabilitation. Those logs--all of them--reported sandstone or shale or both. There was no reference to limestone.

Rocks in vicinity of Elephant Butte have been mapped by Kelley and Silver (1952)* as Cretaceous Mesa Verde formation. They describe the formation to include interbedded lenticular sandstone and shale, siltstone, claystone, conglomerate, and seams of coal. Limestone is not mentioned in their description. In vicinity of the dam, the Mesa Verde is faulted and folded and is in faulted contact with Tertiary clastic sediments. A prominent basalt plug known as Elephant Butte, one-half mile northeast of the dam, served to identify the locale.

Foundation for the Bureau of Reclamation's Elephant Butte Dam was excavated more than 50 years ago, and I cannot speak from personal observation; however, having geologized the dam and vicinity in the last decade, I am confident our colleagues will find the rocks accurately mapped and described by Kelley and Silver. Elephant Butte Dam does not present problems of foundation and abutments in fissured and faulted limestone filled with crevices.

My purpose is not to detract from Mr. Harrington's historical sketch, but to assure engineering geologists that Elephant Butte Dam is New Mexico is not to be cited as an example of a dam built on limestone.

Robert C. Redfield

*Kelley, Vincent C., and Caswell Silver, 1952, Geology of the Caballo Mountains: University of New Mexico Press, Albuquerque

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GEOLOGY IN UNDERGROUND WORKINGS
Lloyd Underwood

SURFACE AND UNDERGROUND GEOPHYSICAL STUDIES AT THE STRAIGHT CREEK TUNNEL SITE, COLORADO
Contributed by James H. Scott and Roderick D. Carroll

Introduction

The U.S. Geological Survey made surface and underground geophysical measurements in the area of the Straight Creek Tunnel pilot bore as part of a general program of research conducted in cooperation with the Colorado Department of Highways. Geophysical measurements of seismic velocity and electrical resistivity were made underground along the walls of the pilot bore. Additional measurements of velocity and resistivity were made on the

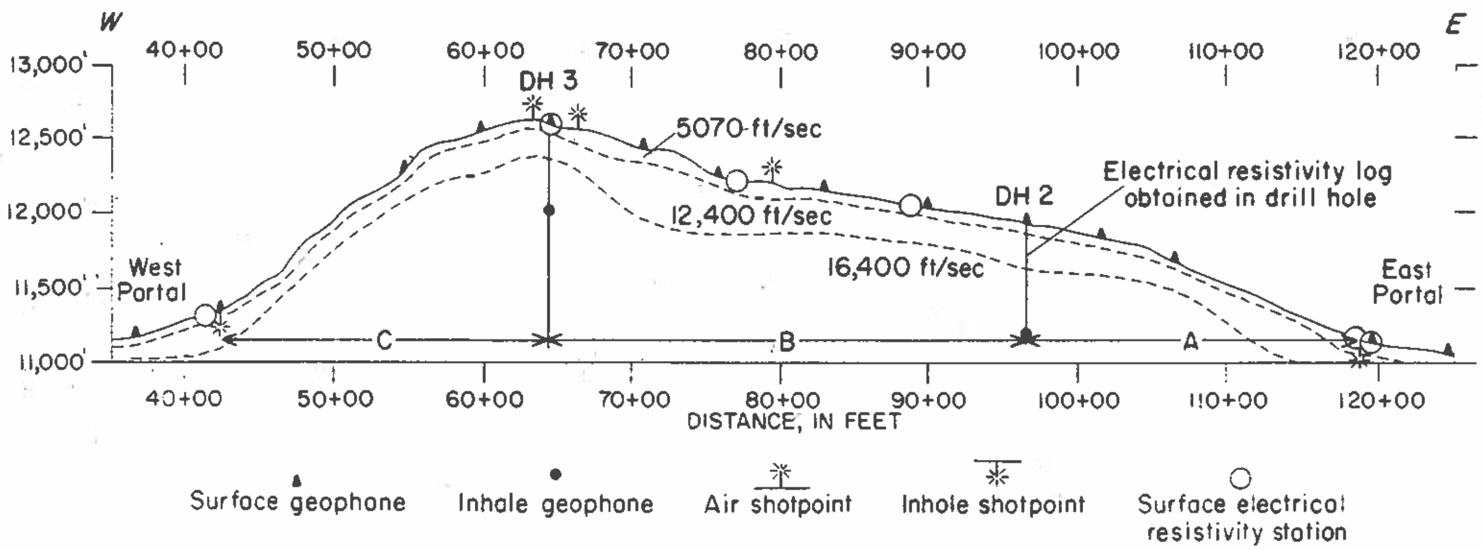


Figure 1. Cross section of Straight Creek Tunnel pilot bore showing surface and in-hole geophysical measurements and interpretations of seismic refraction survey. A B C indicate intervals discussed in text.

surface and in holes drilled from the surface over the line of the bore (Fig. 1).

Bedrock in this area consists chiefly of Precambrian granite (about 75 per cent) with inclusions of Precambrian metasedimentary rock (about 25 per cent -- composed of biotite-rich gneiss, schist, and migmatite), and a few small dioritic dikes of probable Tertiary age. The bedrock is extensively faulted and sheared and is locally altered. Although outcrops are plentiful, most of the bedrock is overlain by thin deposits of colluvium, talus, landslide material, and swamps. Results of the preconstruction-surface geologic mapping were used to predict general geologic conditions and engineering characteristics of the rocks at the depth of the pilot bore.

The pilot bore in which the geophysical measurements were made is approximately 13 feet in diameter and 8300 feet long. The bore is located about 55 miles west of Denver, Colorado, and passes beneath the Continental Divide between the Loveland ski area on the eastern slope and the headwaters of Straight Creek on the western slope of the Rocky Mountains. The pilot bore was driven to obtain geologic and engineering information required for efficient construction of a twin-bore highway tunnel that is to be part of Interstate Highway 70. (For construction rate and cost per linear foot see Figure 2.)

Underground Geophysical Measurements

Underground seismic measurements were made with high-resolution 10-channel refraction seismic equipment capable of detecting energy in the frequency range 10-4000 cps. Accelerometers, used to detect the seismic energy from explosive energy sources, were emplaced along the tunnel walls about 4 feet above the floor in linear arrays that were about 200 feet long. Spacings between accelerometers ranged from 5 to 25 feet. Small explosive charges (0.1 lb dynamite) were detonated in 1-foot-deep shot holes drilled into the rock at both ends and at the midpoint of each array of 10 accelerometers. Average rock velocity along the detector arrays was obtained from these graphs. Interpretations of velocity layering indicated that a zone of anomalously low-velocity rock (4200 to 10,800 ft/sec) surrounds the opening and has a thickness ranging from less than 1 foot to about 17 feet. The existence of this layer is attributed to blast damage and to movement of rock toward the center of the opening along fracture and fault surfaces in response to stresses created by the presence of the bore. This movement, confirmed by extensometer measurements, evidently causes the velocity of rock in the disturbed layer to decrease because of enlargement of gaps along fractures and faults. The velocity of rock behind the anomalous layer is characteristic of the undisturbed rock (13,750 to 20,150 ft/sec).

Underground electrical resistivity measurements were made with conventional Gish-Rooney equipment and special sponge-rubber electrodes impregnated with brine and bentonite to provide good electrical contact with the rock exposed along the walls of the pilot bore. Measurements were made using the Wenner electrode configuration with electrode spacings expanded from 1 to 30 feet in a stepwise manner, keeping the array symmetrical about a center point and parallel with the tunnel axis. This procedure provided a means of interpreting resistivity layering from the surface to a depth of 10 feet or more. Apparent resistivity values obtained from these measurements were corrected for tunnel geometry and plotted against electrode spacing on log-log paper. The plotted points were then interpreted by curve-matching methods using

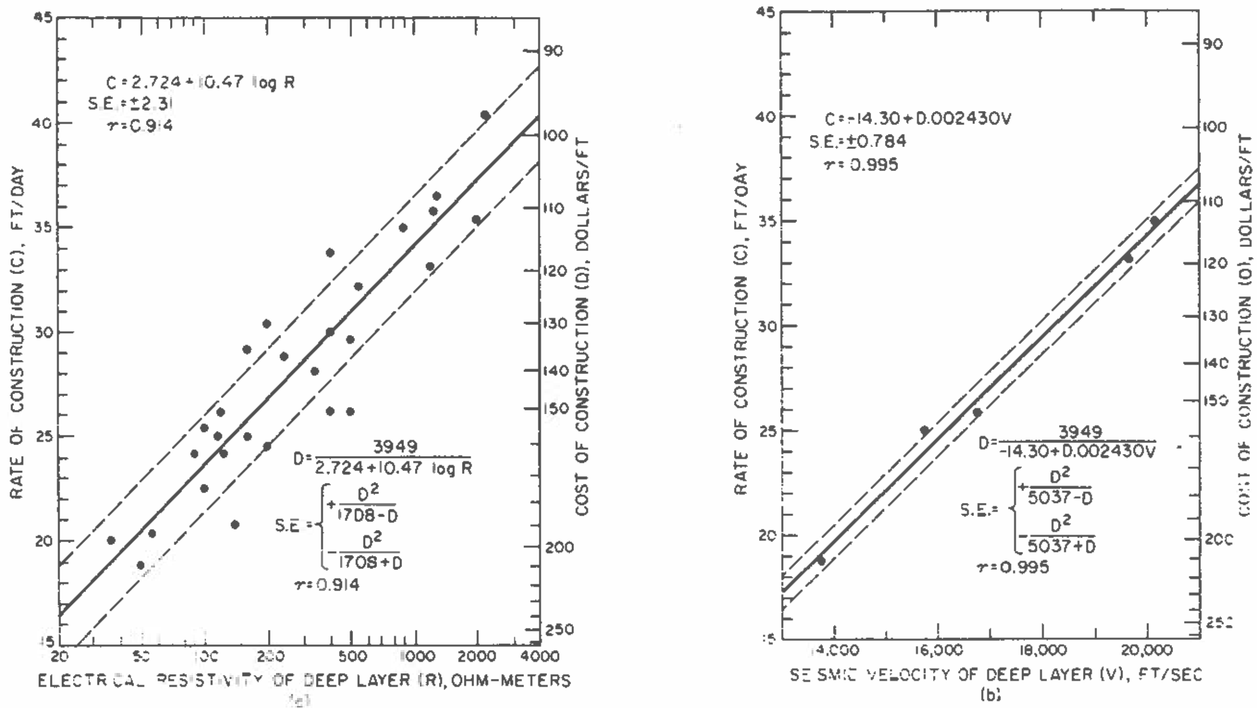


Figure 2. Rate of construction and cost per linear foot plotted against (a) electrical resistivity of deep layer and (b) seismic velocity of deep layer. (Construction data from G. N. Miles, District Engineer, Colorado Dept. Highways, oral commun. March 1965)

theoretically derived curves representing two layers having a variety of resistivity contrasts (Roman, 1960). Interpretations indicated that a rock layer having a relatively high resistivity (60 to 5300 ohm-meters) surrounds the opening and has a thickness ranging from less than 1 foot to about 10 feet. The anomalously high resistivity of this layer is attributed to evaporation of moisture from rock exposed to air. The depth of exposure is probably affected by the depth of severe fracturing caused by blasting. The resistivity of rock occurring behind this layer is characteristic of undisturbed rock (36 to 2200 ohm-meters).

Interpretations of the geophysical data indicated that the layer of high-resistivity rock surrounding the tunnel was generally thinner than the corresponding layer of low-velocity rock. The difference in thickness may be attributed to a difference in the mechanism, causing the anomalous layers detected by the two types of measurements. In electrical resistivity, the anomalous layer is probably caused by evaporation and fracturing chiefly within the blast-damaged zone which, in most places, is restricted to a depth of only a few feet. In seismic velocity, however, the anomalous layer is believed to be caused by the adjustment of rock in response to stress, and subsequent enlargement of gaps along fractures and faults that may occur at depths of 10 feet or more in poor-quality rock.

Results

Results indicated that if correlations such as these were established during the early stages of construction of a new tunnel, or if they were established from previous measurements in a tunnel of similar dimensions, constructed by similar techniques, and in rock of a similar type, predictions of economic and engineering parameters could be made to guide construction in the new tunnel. Predictions could be based on geophysical measurements made on the surface above the tunnel, or on measurements made underground in feeler holes drilled ahead of the working face.

Statistical correlations of underground geophysical data were made with engineering and construction-design considerations such as rock quality, height of tension arch, stable vertical rock load, set spacing and type of support, lagging and blocking, rate of construction, and cost per foot. Results of these correlations presented by Scott and Carroll at the 46th Highway Research Board meeting (January 1967) showed that geophysical measurements have great promise in underground work.

It is expected that the entire paper by Scott and Carroll will be published sometime in 1967. A companion paper, "Results of Geologic Research, Straight Creek Tunnel Pilot Bore, Colorado" by Charles S. Robinson and Fitzhugh T. Lee, describing predictions of various parameters of interest in tunnel construction based chiefly on surface and drill-hole geological studies, was also presented at the January meeting of the Highway Research Board and should also be published in 1967.

CONFERENCES AND ACTIVITIES OF SOCIETIES
R. E. Goodman

NSF to Sponsor Short Course on Rock Mechanics at Boston College

With the objective of providing college teachers of structural geology with background in rock mechanics so that they may bring more quantitative ideas into their courses, Boston College will offer a seminar June 26-June 28, 1967. The course will be directed by Dr. E. G. Bombolakis with Dr. Robert Riecker serving as Associate Director. Others lecturing in the course will be W. M. Chapple, W. F. Brace, David Stearns, Robert Merrill, Hugh Heard, Neville Carter, and Fred Donath. Inquiries may be addressed to the Director in care of the Geology Department, Boston College, Chestnut Hill, Massachusetts 02167.

University of Nevada Presents a Conference on Earthquakes and Earthquake Engineering

Under the direction of Alan Ryall, D. B. Slemmons, and John Bonell, 70 earth scientists and structural engineers participated in NSF-sponsored discussions of engineering seismology in Reno last summer. In the first part of the course, Seismology, lecturers included Perry Byerly, James Brune, Cinna Lomnitz, Jack Oliver, Pierre St. Amand, William Stauder, and Don Tocher. Part II, concerned with faulting, included as lecturers John Crowell, Ray Marsell, and Gordon Oakeshott. Earthquake vibrations and anti-seismic design were discussed in the last part of the conference by John Blume, Ray Clough, Henry Degenkolb, George Housner, Donald Hudson, Paul Jennings, William Moore, John Rinne, H. B. Seed, and Karl Steinbrugge. It is intended that the proceedings will be published.

Upcoming Conferences

Fifth Annual Symposium on Engineering Geology and Soils Engineering

Idaho State University, Pocatello, will host this year's meeting. The series is attended by several hundred engineering geologists, soils engineers, highways engineers, and others primarily from the northwest. The dates: April 12-14, 1967.

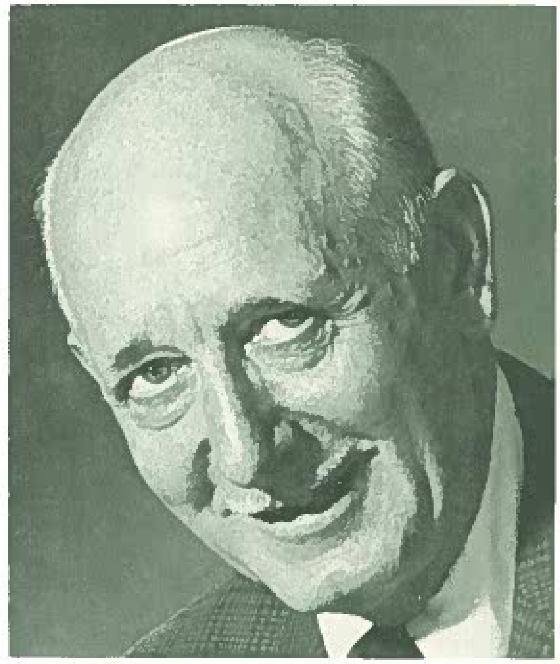
Ninth Symposium on Rock Mechanics

Colorado School of Mines will host this year's annual Symposium on Rock Mechanics, April 17-19, 1967. Inquiries should be addressed to Prof. Niles Grosvenor (Colorado School of Mines, Golden, Colo.)

ACTIVITIES OF ENGINEERING GEOLOGISTS
Arthur Cleaves

Dr. Tor Brekke, Senior Lecturer of Engineering Geology at Technical University of Norway, Trondheim, is visiting this year at the University of California, Berkeley, as a guest of the Department of Civil Engineering. In addition to visiting sites of engineering works around the country, he is pursuing an investigation of engineering geological aspects of stability problems in underground construction. Dr. Brekke will give a number of public lectures on this subject.

Dr. Robert W. Karpinski, Professor of Geology at the University of Illinois (Chicago Campus) and best known to us as our Chairman, has been awarded



Robert W. Karpinski

a Certificate of Appreciation by AGI "in recognition of his interest in and contributions to the geological sciences, especially as founder of the Committee of 1000 of AGI."

Paul M. Merifield and Donald L. Lamar, consulting geologists (Earth Science Research Corp., Santa Monica, Calif.) have received a contract from the Department of the Navy to study the engineering geology of central San Clemente Island, California. Detailed surface mapping will be supplemented by core drilling (Buena Engineering, Ventura, Calif.) and acoustical profiling and offshore sampling (Western Offshore Group, North Hollywood, Calif.).

Jack E. Kelly, formerly Chief Geologist for International Engineering Company of San Francisco, has joined Keith E. Anderson, Consulting Engineer and Geologist of Boise, Idaho, in a new partnership, Anderson and Kelly. The partnership will specialize in engineering and geological aspects of water development and utilization, including ground-water investigations, dam and reservoir studies, irrigation and drainage development, and related fields of interest.

NEW BOOKS AND LITERATURE IN ENGINEERING GEOLOGY
Raymond E. Whitla

ROCK BREAKUP THEORY, Journal of the American Concrete Institute, v. 63, no. 9, NL10-NL11, NL15-NL16, September 1966

This is a condensation of an article in Rensselaer Review, v. 3, no. 1, p. 13-17, March 1966. Either one of these articles should prove to be of interest to persons who are concerned with evaluating rock for use as protection stone, such as riprap or breakwater stone. Scientists have long held that rock breakup on exposure to weather was due principally to freezing and thawing. The scientists at Rensselaer Polytechnic Institute have concluded after extensive experiments on a series of rocks that water absorbed inside the small rock pores is largely unfreezable at temperatures as low as -40°C and have postulated that frost sensitivity is related largely to the expansion of absorbed unfreezable water rather than to the transition of water to ice.

ESSA SYMPOSIUM ON EARTHQUAKE PREDICTION, ROCKVILLE, MARYLAND, FEBRUARY 7, 8, 9, 1966, U. S. Department of Commerce, Environmental Science Services Administration, 167 p., 1966 (Available from the Superintendent of Documents, Washington, D. C. 20402, price $1.00)

This publication contains the 31 papers that were presented at a symposium held at the Rockville, Maryland, headquarters of the Environmental Science Services Administration, February 7-9, 1966, for the purpose of clarifying ESSA's technical capability in the field of earthquake prediction. The symposium contains seven papers pertaining to or related to the physical basis of earthquakes, 12 papers pertaining to instrumenting earthquake fault zones, five papers dealing with engineering seismology and earthquake engineering, and seven papers dealing with geophysical and geological surveys of earthquake fault zones. The papers are short, and, in addition, an overall summary is presented that abstracts the main ideas in each paper.

FOUNDATION GROUTING: PLANNING, Department of the Army, Office of the Chief of Engineers, Engineer Manual EM1110-2-3501, 48 p., July 1, 1966 (Available from the U.S. Army Engineer Waterways Experiment Station, P. O. Box 631, Vicksburg, Miss. 39181, price $0.75)

A preliminary engineering manual on foundation grouting was issued by the U. S. Army Corps of Engineers in 1949 as three chapters of the Engineering Manual for Civil Works Construction. These three chapters later were assigned engineering-manual numbers EM1110-2-3501, EM1110-2-3502, and EM1110-2-3503, respectively. EM1110-2-3501, dated July 1, 1966, is a revision, bringing up-to-date the older grouting manual of the same number and title. The manual was prepared as a guide for persons responsible for the planning of foundation-grouting programs and is written primarily around the grouting of bedrock foundations using portland cement as the principal grouting material. Other grouting materials, however, are discussed, and the bibliography at the end lists 118 selected references on grouting.

Carder, Dean S., Editor, EARTHQUAKE INVESTIGATIONS IN THE WESTERN UNITED STATES, 1931-1964: U. S. Coast and Geodetic Survey Publication 41-2, 264 p., 1965 (Available from the Superintendent of Documents, Washington, D.C. 20402, price $2.75)

This volume reviews the development of earthquake research in the United States and presents results of the investigation since the program's inception in 1931. It contains 11 papers, two on the development of the earthquake-investigation program, five on instruments and instrumental studies, and four on damage studies.

Waller, Roger M., EFFECTS OF THE EARTHQUAKE OF MARCH 27, 1964, IN THE HOMER AREA, with a section by Stanley, Kirk W., on BEACH DAMAGES ON HOMER SPIT: U.S. Geological Survey Professional Paper 542-D, 28 p., 1966

McCulloch, David S., SLIDE-INDUCED WAVES, SEICHING AND GROUND FRACTURING CAUSED BY THE EARTHQUAKE OF MARCH 27, 1964, AT KENAI LAKE, ALASKA: U.S. Geological Survey Professional Paper 543-A, 39 p., 1966

Here are another two of the series of reports being published by the U. S. Geological Survey on the 1964 Alaska Good Friday Earthquake. Three other publications in the series have been reported previously. U.S.G.S. Professional Paper 542-D by Roger M. Waller and Kirk W. Stanley describes the effects of the earthquake on the small town of Homer, Alaska, on the southern tip of the lowland part of Kenai Peninsula. Damages here were caused by landmass subsidence, earth-flows, landslides, seiche waves, and submarine landslides. U.S.G.S. Professional Paper 543-A by David S. McCulloch discusses landslides from deltas in Kenai Lake and evidence of local damaging waves caused by the slides and other earthquake phenomena at Kenai Lake. The report contains a bathymetric map and profiles of Kenai Lake and a map of wave damage and sliding at Kenai Lake.

Smith, F. G., GEOLOGICAL DATA PROCESSING: USING FORTRAN IV: Harper and Row, New York, 284 p., 1966, price $14.00

I have not seen this book, but it is described as a survey of applied mathematics used by geologists in research and in translation of problems into language for computer use with rules and examples of data processing.

A GEOLOGIC MAP FOR YOUR GLOVE COMPARTMENT

AAPG has published an excellent map of the mid-continent region, part of its ambitious geologic highway map series. This map, compiled by Philip Oetking, Dan Feray, and H. B. Renfro, covers Kansas, Oklahoma, Missouri, and Arkansas. Price: $1.00 ($1.25 rolled) from AAPG, P. O. Box 979, Tulsa, Oklahoma 74101. It includes cross sections, a physiographic map, a tectonic map, and a discussion of the historic geology of the region.

ENGINEERING GEOLOGY IN SOUTH AUSTRALIA

Contributed by Dr. K. R. Miles

In Australia, the engineering geology profession is growing rapidly. There are at present about 80 practicing engineering geologists, mostly in government service, both as members of geological surveys and of engineering organizations.

The rapidly growing State of South Australia (area 380,070 square miles, population 1,090,000) presents a wide variety of projects for engineering geologists, and these are being tackled mainly by the Engineering Geology Section of the Geological Survey. The Section's seven-man team has, in the last few years, been involved in problems ranging from water-supply tunnels and concrete-arch dams in hard rocks, to building foundations on expansive clay soils in some areas, and collapsing silts and sands in others.

About 83 per cent of the State has an average annual rainfall of less than 10 inches, and only 0.3 per cent receives more than 30 inches of rain per annum, so that water-conservation projects loom large in the economy of the State. Such projects and their attendant geological problems provide a continuing challenge to the profession of engineering geology in South Australia, and this challenge is being faced with vigor and enthusiasm.

The Geological Survey is a part of the Department of Mines, which has a large fleet of cable-tool, rotary, diamond, and auger drills. In addition to work on mining and ground-water supply projects, the drilling organization carries out a large amount of soil and rock sampling for foundation purposes. The engineering geology and drilling teams are, therefore, able to provide an integrated geological investigation and sampling service which is available both to other government and semi-government organizations and to the general public.

THE ENGINEERING GEOLOGIST

Editor: Richard E. Goodman (475 Hearst Mining Building, University of California, Berkeley, Calif. 94720)

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