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The Engineering Geologist

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SAN FRANCISCO -- SCENE OF ANNUAL MEETING
November 14-16

Engineering geologists will want to attend the GSA annual meeting this year. There will be five sessions devoted to some of the most pressing problems in the field -- siting of nuclear reactors, rapid transit, active faults, and land subsidence. Many of the papers in other sessions are also of special interest to engineering problems, particularly in the sessions on marine geology, hydrogeology, coal geology, structural geology, Pleistocene geology, geomorphology, extra-terrestrial processes, carbonate sedimentology, information retrieval, and geophysics.

If you have not already contacted Mr. Elmer Marliave about your field trip preferences for the annual meeting, please do so. (4466 N. Park Drive, Sacramento, California 95821) See previous issue of The Engineering Geologist for description of field trips.

CALIFORNIA EARTHQUAKE INVESTIGATIONS -- A REVIEW

Raymond C. Richter

The historic record of earthquakes in California dates back to 1769. In general, the study of California earthquakes has been largely a scientific pursuit, a seeking of knowledge of the fundamental mechanics of earthquakes, and a documentation of the effects of earthquakes on man, his structures and the land. Only in recent years, since the early 1930's, have earthquake studies become oriented, in part, to the safe and economical design of engineering structures.

As California's population and supporting agricultural and industrial base continue to grow at a phenomenal rate, a twofold seismic risk rapidly develops. First, more people and facilities are crowded into existing high earthquake risk areas. Second, these people and facilities are spread over the length and breadth of the State, thus increasing the probability of an earthquake of damaging intensity being centered beneath a populated area. In view of this rapidly expanding population, and since it remains beyond the capabilities of man to influence the regimen of earthquakes, the only practical course in California is to avoid occupying seismically hazardous areas insofar as practicable and to reduce destructive effects of earthquakes through proper design and competent construction practice. To accomplish these ends, better methods for evaluating seismic hazards at construction sites must be developed, procedures for designing economical structures that will withstand these hazards must be periodically reviewed and improved, design manuals and building codes must be revised accordingly to insure competent construction, criteria for developing adequate zoning laws must be established, and guidelines should be created for developing meaningful earthquake loss insurance programs or other measures to hold down earthquake damage costs. Economically unwarranted uses of high earthquake risk areas should be eliminated without prohibiting meritorious uses for these regions.

How well is California meeting these broad objectives ? Many important steps have been taken toward realizing them. However, much of the effort has been diversified in that many groups and technical specialities have been more or less independently studying earthquake problems. There is need for greater coordination of work toward the foregoing objectives so that the State will be prepared for the next critical 50-year period, when California will be experiencing its most rapid buildup of people and supporting facilities.

California's requirements are for increased knowledge of earthquakes and related phenomena, better aseismic design procedures for engineering structures, and appropriate legislation. A comprehensive program of investigation concentrating on these three factors with the objective of producing results both meaningful and understandable to engineers, builders, administrators, and legislators could go a long way toward reducing possible loss of life and destruction at the time of the next great earthquake which California will surely experience. The advancements in earthquake engineering, which are sought can be aquired only through the coordinated efforts of structural engineers, seismologists, engineering geologists, and other technical specialists. Expensive instrumentation and highly technical studies are essential. Earthquakes are a California problem, therefore, it behooves California investigators whether in universities, state and local governments, or private practice to take a more active and responsible role in the study of earthquakes in order to accomplish California's earthquake requirements.

Summarized below are some of the significant developments in the study of California earthquakes since about 1887.

1. About 1887, the first systematic compilation and publication of earthquakes on the Pacific Coast was inaugurated by E. S. Holden, President of the University of California and Director of the Lick Observatory. The first publication, covering the period 1769 to 1897, was released as Smithsonian Miscellaneous Collections, No.1087.

2. In 1887, the first of several sensitive seismograph stations were installed in the San Francisco Bay area at Lick Observatory, Mills Seminary, and the University of the Pacific. This makes the University of California at Berkeley the oldest seismographic observatory in California.

3. In the late 1880's, the U. S. Coast and Geodetic Survey established the first comprehensive triangulation net with respect to several major fault systems in California. About this same time, the U. S. Geological Survey, and the predecessors of the California Division of Mines and Geology, commenced geologic studies in California.

4. Following the destructive San Andreas earthquake of April 18, 1906, which caused extensive damage to San Francisco and adjacent areas, a State Earthquake Investigation Commission was formed to study all aspects of the earthquake and the resultant damage to all types of engineering structures. Funds for operation of the commission and publication of its findings were provided by the Carnegie Institution in Washington, D. C. Soon after the earthquake, the U. S. Coast and Geodetic Survey remeasured its triangulation net in the area to determine the width of the zone affected by crustal movement.

5. In 1907, A. G. McAdie, U. S. Weather Bureau Meteorologist in charge of the San Francisco office, released a descriptive catalog of Pacific Coast earthquakes for the period 1897 to 1906. This publication was released as Smithsonian Miscellaneous Collections, Vol. XLIX, No. 1721.

6. After publication of the report of the Earthquake Investigation Committee in 1908, adverse public "earthquake psychology" developed which opposed discussion or investigation of earthquakes, because it was "bad for business". In the midst of this opposition, a group of dedicated San Francisco Bay area geologists, seismologists, and others organized the Seismological Society of America. Bulletins of that society have been issued quarterly since 1911 and constitute one of the significant publications relating to California earthquakes. Funds to support earthquake investigations in California came largely from outside the State during those lean years -- mainly from the Carnegie Institution of Washington. In 1910, new sensitive seismographs were installed at the University of California at Berkeley, and at Lick Observatory.

7. In 1921, Carnegie Institution of Washington released a report recommending five areas of earthquake investigations in California, including: study of faults; study of surface displacements; study of isostasy; instrumental development; and a Southern California seismograph network. About 1923, the torsion seismometer was developed for this work by J. A. Anderson and H. O. Wood. By the summer of 1929, seven seismograph stations had been installed in Southern California.

8. The damaging offshore submarine earthquake which struck Santa Barbara on June 29, 1925, reawakened public interest in earthquake investigations. As a result, new equipment was installed at Stanford University and at San Francisco.

9. During the period 1925 to 1940, California Institute of Technology at Pasadena, pioneered research in problems of strong earthquakes and the development of practical earthquake engineering principles.

10. In 1926, the earthquake department of the Board of Fire Underwriters of the Pacific showed, after careful study, the general inadequacy of existing building codes. This study spurred insurance companies, architects, contractors, and engineering organizations to develop a Uniform Building Code for California.

11. In 1926, the City of Palo Alto adopted an earthquake building code.

12. In 1928, the U. S. Coast and Geodetic Survey, San Francisco field office, began publishing descriptive notes of earthquakes which had formerly been published by the U. S. Weather Bureau and Lick Observatory.

13. In the early 1930's, the U. S. Coast and Geodetic Survey began making periodic geodetic measurements along and across the San Andreas fault at a few critical localities with a view to accurately determining the rate and direction of earth movements. Surveys across the fault from Monterey to Pacheco Pass were made in 1930, and continued in 1932 in the area from San Luis Obispo to Lost Hills, and from San Fernando to Bakersfield. Other projects followed in subsequent years and are being repeated at 10-year intervals, supported by federal funds.

14. In 1931, federal funds were made available to the U. S. Coast and Geodetic Survey to implement a program of strong-motion instruments throughout the State. Prior to that time, no appreciable instrumental data useful in the design of engineering structures had been obtainable near epicenters of large earthquakes, because the initial shock almost always put sensitive siesmographs out of order. This important development enabled the recording of critical ground motion data near epicenters. The U. S. Coast and Geodetic Survey gradually expanded its program. Before the 1933 Long Beach earthquake, several instruments were installed in the Los Angeles and Long Beach areas. The U. S. Coast and Geodetic Survey now operates and maintains approximately 80 strong-motion instruments in California, mainly in the Los Angeles and San Francisco areas, plus an additional 34 instruments in a cooperative program with the California Department of Water Resources.

15. The damaging offshore submarine earthquake which struck Long Beach in March 1933 again awakened public interest in earthquakes, particularly with respect to their effect on buildings and schools. As a result of extensive damage to public schools, the Field Act was passed by the California Legislature. This Act brings all new public school construction under standards set by Title 21 of the California Administrative Code under the direction of the California Division of Architecture.

16. Following the 1933 Long Beach earthquake, earthquake design provisions were incorporated in the building code of the City of Los Angeles, and in the Uniform Building Code.

17. In the 1930's, studies of earthquakes related to effects on engineering structures were initiated by personnel of Stanford University. A shaking table was designed and studies carried out on the vibratory behavior of soils, on dynamic pressure of fluids, and on absorption of energy during vibration.

18. In 1937, California Institute of Technology took over the administration of the 1921 Carnegie Institution program of earthquake recording and testing in Southern California.

19. In 1939, S. Townley and M. Allen, released a descriptive catalog of Pacific Coast earthquakes for the period 1769 to 1928. This publication appeared as Vol. 29, No. 1 of the Bulletin of the Seismological Society of America.

20. Following the war years 1941-1945, the leading universities in California (University of California at Berkeley, University of California at Los Angeles, Stanford University, and California Institute of Technology) implemented earthquake engineering programs which continue at present and have resulted in some significant contributions with respect to design of engineering structures. Cal Tech's program, which was initiated in the mid-1920's, was expanded beyond the field of basic research.

21. In 1947, the California Department of Water Resources commenced earthquake hazard evaluation studies of hydraulic structures associated with the California Water Plan. These studies were expanded in 1956-57 when design studies were initiated for unit features of the State Water Facilities.

22. In 1948, The U. S. Coast and Geodetic Survey, in cooperation with seismologists, prepared a seismic risk map of the United States which identified four levels of seismic risk. The map was removed by the Survey in 1952 following protests by various groups interested in securing lower risk ratings in specific localities.

23. In the 1950's, the City of San Francisco adopted earthquake provisions in the building code.

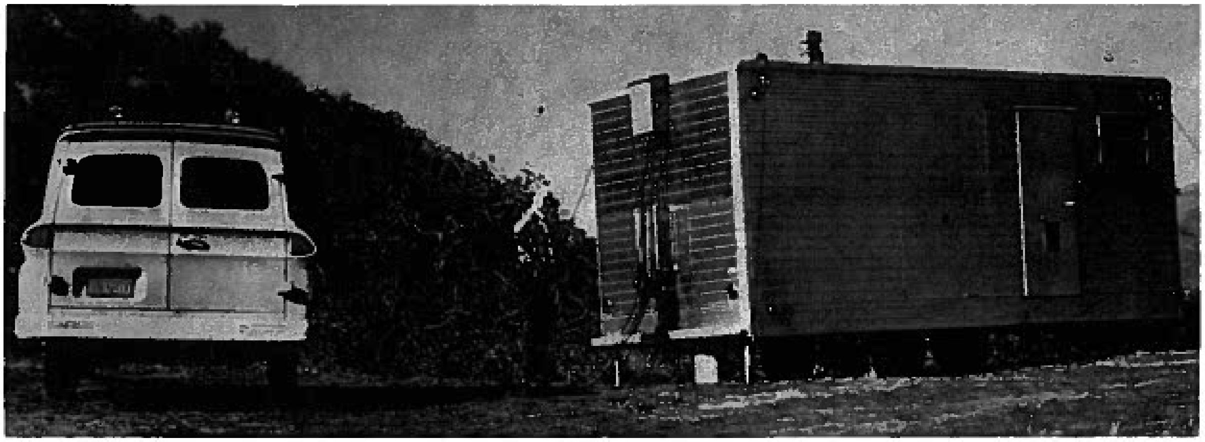
24. In 1952, following the destructive White Wolf fault earthquake of July 21, 1952, the California Department of Water Resources released a report on field investigations of earthquake damage to various types of engineering structures.

25. Since 1953, the California Division of Architecture has implemented an earthquake research program investigating various structural aspects of public school construction. One aspect of the program was aimed at establishing the strength or ability of wood diaphragms to resist earthquakes.

26. In the mid-1950's, the federal sponsored VELA Uniform program to distinguish underground nuclear explosions from natural earthquakes, made available to California earthquake centers large amounts of money. This program was a tremendous boost to the development of sophisticated seismic instrumentation and data processing systems.

27. In 1955, the California Division of Mines, serving as editor, solicited technical articles from earthquake experts and released a comprehensive symposium on the White Wolf earthquake of July 21, 1952, which appeared as their Bulletin 171.

28. In 1959, the California Department of Water Resources initiated a comprehensive interdisciplinary earthquake engineering program oriented to the safe and economical design of hydraulic structures required for implementation of the California Water Plan. The program has the guidance of an eminent board of consultants. It is in part a cooperative investigation with the U. S. Coast and Geodetic Survey and the University of California. Its activities comprise earthquake data collection and analysis, earthquake hazards evaluations, and earthquake engineering criterial development and evaluation. A significant portion of the Department's program is instrumentation and includes: sensitive seismograph stations at Oroville and other dams as constructed; 34 strong-motion instruments at key engineering structures to determine ground response and the first strong-motion array ever constructed across the San Andreas fault; two mobile seismic laboratories for determining spectral response of foundations of key engineering structures (see photograph on next page), six mercury liquid-level type tilt-meters for monitoring small differential movements of the ground surface at pumping plants; twenty special fault movement quadrilateral using refined optical surveying methods; an extensive leveling program to detect land subsidence and elevation; special research studies aimed at determining the seismic resistance of earth embankments; and extensive



California Department of Water Resources mobile seismograph trailer used for determining spectral response of foundations of key engineering structures in the State Water Facilities.

geodimeter measurements which monitor movement along the San Andreas and other fault systems in California. Annual movement along these fault systems has been determined for the first time and correlations between observed changes in rate of movement preceding earthquakes may constitute a major breakthrough in earthquake prediction.

29. In the fall of 1964, the California Institute of Technology initiated a comprehensive two-year program to study the San Andreas fault. Extensive instrumentation will be utilized in an attempt to secure a better understanding of the San Andreas fault, to evaluate its movements, and hopefully to predict future earthquakes. Results of these studies will have a significant bearing on the design of engineering structures near the fault, and on foundations of poor quality rock in adjacent areas.

30. In December 1964, an Earthquake and Geologic Hazards Conference, sponsored by the Resources Agency of California, was held in San Francisco. The main purpose of the conference was to seek guidance concerning the role and responsibility of the State of California in leading and coordinating investigations of earthquakes and related geologic hazards, in conducting such investigations, and in disseminating the results of earthquake investigations. One of the significant developments of this conference was the establishment of two committees by the Administrator of the Resources Agency of California. These two committees, whose charge was to define the scope of earthquake studies to be undertaken by the State, and the State organization to undertake and coordinate these studies, will submit their recommendations late in 1966.

31. In December 1964, The University of California at Berkeley announced the University's plan to construct a multipurpose geophysical laboratory near Hollister. This laboratory will allow a large amount of information to be recorded at one site including: long-term recording of elastic and acoustic waves; tilt, strain and conductivity fluctuations; and variations of magnetic, gravity and heat fields.

32. About July 1965, the U. S. Geological Survey established a National Center for Earthquake Research at Menlo Park, California. This group will have many earth scientists studying the western states' earthquake belt. About the same time, earthquake investigations of the U. S. Coast and Geodetic Survey in California were accelerated. Increased activities of these two federal bodies in California stem from recommendations from a Presidential Advisory Board concerning the devasting Alaska earthquake of 1964. The Board recommended a 10-year program, of about $137m., directed toward earthquake prediction and engineering in California and Alaska.

ENGINEERING GEOLOGY FOR DAMS

W. Harold Stuart

Elephant Butte

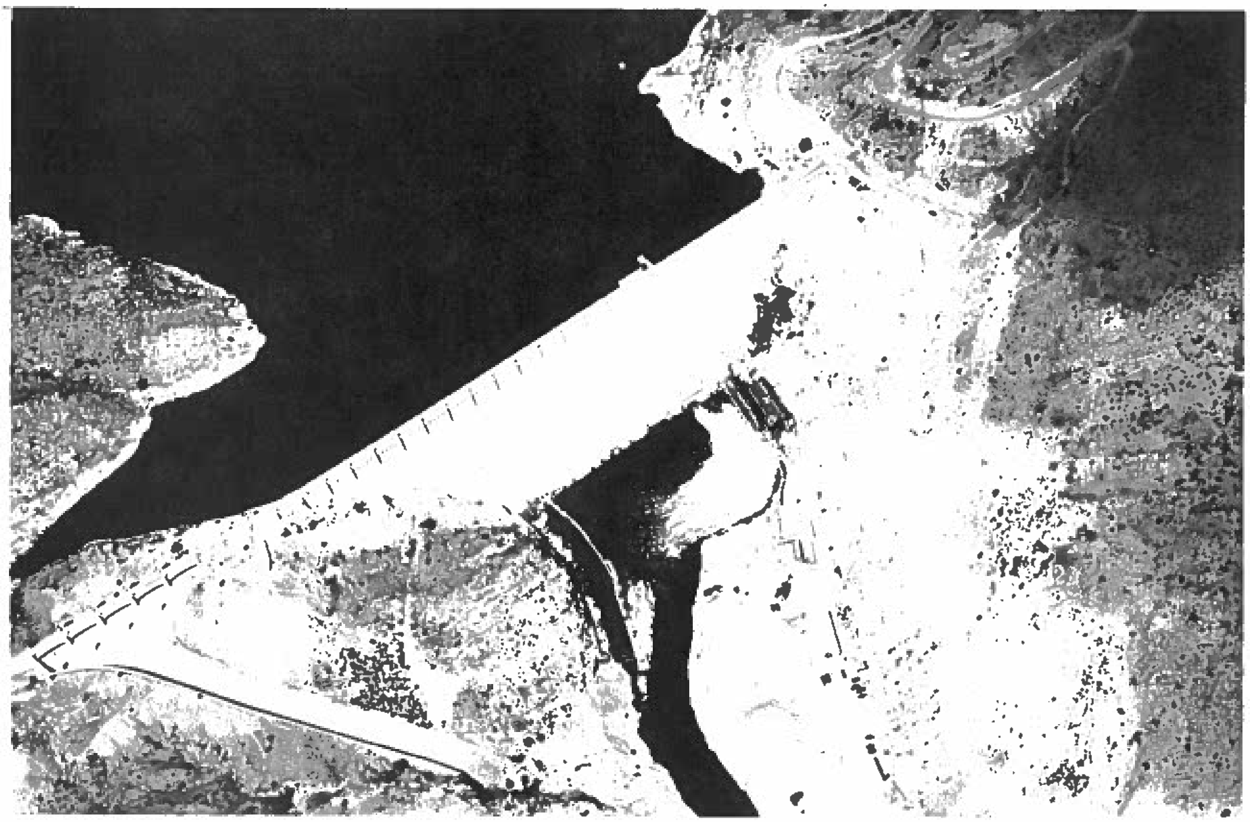
-- contributed by E. R. Harrington --

In these enlightened days those who select sites for dams consider the engineering geologist as a necessary part of the team. They have come to realize that this is an indispensable part of any selection, if the structure is to stand. This accomplished fact of 1966 was not yet apparent fifty years ago. Dams were few and small in the pre-1910 days;the large structures were yet to come. Perhaps the first big one was the Elephant Butte Dam in the Rio Grande of New Mexico about 1910. This structure was designed to impound a lake having capacity in excess of two and one-half million acre feet. Approximately fifteen years were to pass before the Reservoir at American Falls in Idaho topped that capacity. Elephant Butte was the structure that set some styles for other great structures that have followed throughout the world.

The site for Elephant Butte Dam was picked by people who were hunting for a place that looked good for such a structure. The Rio Grande some centuries before had been crowded from its old bed by a lava flow near Socorro, New Mexico. The river had been forced out of its old channel and across the southwestern edge of the upturned Caballo Mountains. The channel was narrow and the proposed dam could be well braced between canyon walls. It looked good to the scouts who were not geologists. The walls were of rock, weren't they ? And a rock is a rock, isn't it ? Well, yes, and no. Those walls were of limestone, bent and faulted, and filled with crevices. It is very doubtful if this site would be considered at all by a geological engineer but it was selected without thought of seeking any advice.

There was a lot "riding" on this dam. It was the first big structure that the reclamation people had been able to sell to Congress and to the nation. What happened to this one could well set the tempo for future structures. A failure here could hold back additional reclamation work for decades to come. This dam had to get its job done and right at the start this meant it had to hold water. On the construction end of the job Big Jim French took charge. Jim was a big gent;tall, wide, and rugged. He was well trained in books and he had taken some years of postgraduate work in the tough university of hard knocks. He looked at that fissured and faulted limestone as it was uncovered by the steam shovels and shuddered. The first consideration of any dam was that it hold water. This one had two and one-half strikes on it right at the start !

Jim French called in the President of the New Mexico School of Mines, Dr. Fayette V. Jones, and they looked over the site. They were appalled by the possibilities. But Dr. Jones borrowed some of those new diamond drilling outfits from a big copper mining outfit over to the west. Between the Jones and French crews they riddled the seamy foundations with those diamond drill holes and they did perhaps the nation 's first big job of grouting. Their machines were designed right on the job and grouting history was made about 1911. It held. It has been holding well over fifty years;no leaks. It was an example of cooperation between two great pioneers, each of whom recognized that he did not know it all;that he needed help. French was a big man who wore high laced boots heavily hob-nailed. His feet were big even for a big man. Jones was small, wiry, real dressy, and as hard as a piece of quartz. They made a good pair.



Elephant Butte Dam from the air

The structure was turned over to the Government late in 1914. On the approach road there was a large sign board telling about the Dam: the size of the reservoir;cubic yards of concrete, etc. Neatly printed in pencil, letters about an inch high, was an added contribution inscribed by some desert Byron:

Here's to Jim French and his great big feet
Gathering the dope for the contour sheet;
But if it hadn't been for Jones and his Diamond Drill Rod
There'd be no Dam at the Butte, By God !

I like that. I believe it stands as a fitting epitaph to two great men who got together on the first of the nation's great dams and who did it right.

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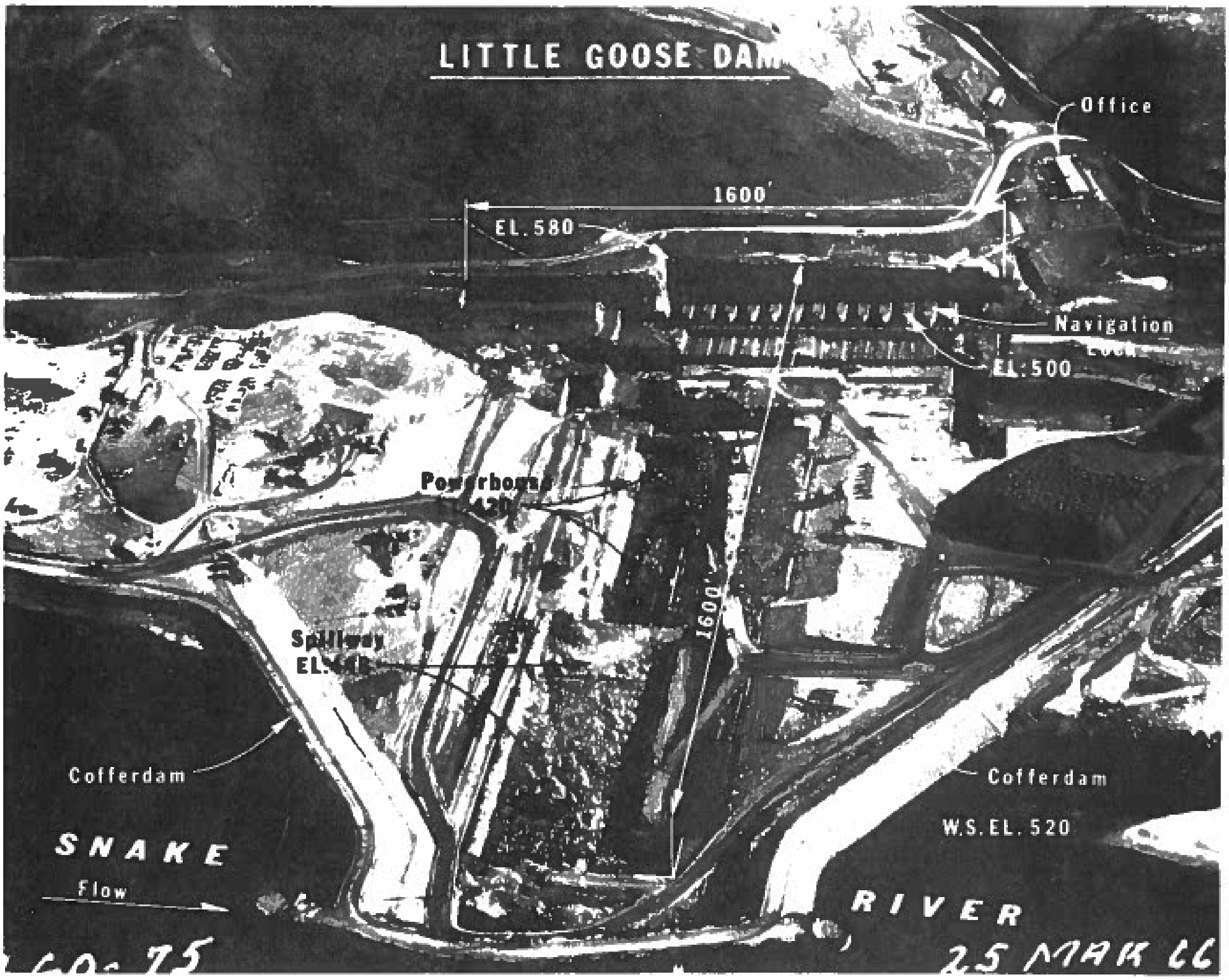
Carters Dam

-- contributed by Wm. V. Conn --

A high rockfill dam is being constructed by the U. S. Army Corps of Engineers on the Coosawattee River at Carters, Georgia. It will be the largest and highest dam of its type in the eastern United States. It is of special geological significance in that it is only a few hundred feet upstream of the contact between the Paleozoic rocks of the Valley and Ridge Province on the west, and the metamorphics of the Ocoee series to the east. As a part of the dam construction a tailrace will be excavated across this contact, providing for the first time an opportunity to study the fault in a large exposure of fresh, unweathered rock. It is expected that the excavation will be completed by fall of this year.



Little Goose Lock and Dam
-- contributed by Earl Chandler --

Little Goose Lock and Dam is one of a system of eight dams designed to provide slack water navigation from the Pacific Ocean to Lewiston, Idaho, a distance of 465 miles. It is located on the Snake River approximately 70 miles down river from Lewiston in an area where the Snake River is now entrenched some 1200 feet into the Columbia River basalts. The entire dam with the exception of the north earthfill embankment is being built behind a single cofferdam. This enabled the Contractor, Vinnell-Mannix-Fuller-Dillingham, to complete all excavation work before concrete placement began (see photo above). The usefulness of presplitting in controlling rock breakage is also well illustrated in the navigation lock area where excavation for the buttress wall stems required careful and precise blasting methods. The dam is scheduled for completion by midsummer 1970. During early site explorations, artesian waters were encountered about 180 feet below the surface of the bedrock in the valley floor. The pressure in this aquifer is equivalent to a hydrostatic head of approximately 330 feet. Since there is evidence that this is a "leaky" aquifer which may transmit artesian pressure to the base of the dam, design features were incorporated into the structures to compensate for this possibility. These features include additional foundation drains, buttress type lock monoliths with their decreased base areas and provision for all drain holes to be drilled at an early stage of construction. The existence of the artesian condition increased the importance of the engineering geologist's role in design. In addition to a program of flow tests, holding tests and pressure tests, very careful interpretation of the cores recovered from some 270 rotary drill holes formed the basis for decisions relating to uplift pressures and the compensating design features.

GEOLOGY IN UNDERGROUND WORKINGS

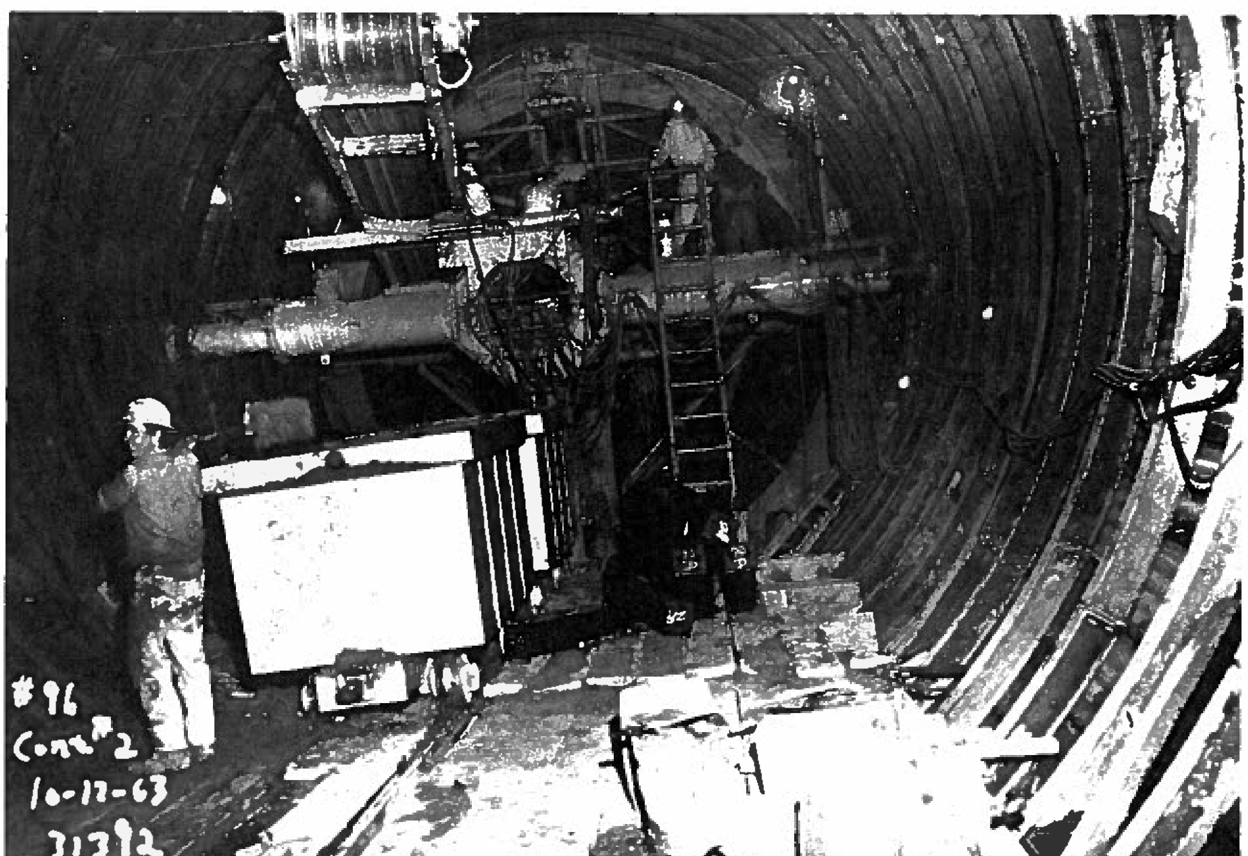
Lloyd Underwood

Instrumentation Moves Ahead In Chicago Tunnel

In the April 1966 issue of this publication we briefly reviewed the elaborate instrumentation program for tunnel design being planned by the Metropolitan Sanitary District of Greater Chicago. Recent correspondence from Mr. George J. Malina, Project Engineer, reads as follows:

"The contract on which the initial instrumentation is proposed has been awarded. The bids were quite satisfactory and the contractor's interest in instrumentation is very high. The contractors are beginning to realize that instrumentation can be of benefit to them as well as to the owners."

The S. A. Healy Co. of Chicago holds a $9.4 million contract for a portion of the 58 mile long Northwest Interceptor Sewer Project. A Caldweld electro-hydraulic tunneling machine has been averaging 5 feet per hour in a tunnel that varies in diameter from 23 1/2 feet to 26 feet. Initial portions of the tunnel were in saturated clay with inclusions of sand and silt, and then the contractor entered a reach of tunnel of composite material. The lower third of this face is dolomite limestone. Above this is a ledge of rock up to 6 feet high, that must be blasted ahead of the eight spoked cutter wheel. Above springline, the material is silty clay with pockets of fine-grain sand.



26 ft. bore through cohesive glacial tills for 20 ft. finished sewer

BUILDING CONSTRUCTION AND LAND DEVELOPMENT

Gary Melickian

The writer would welcome comments and experiences by others. This will provide a means of keeping the profession informed about engineering and geologic developments related to building construction and land development. Comments, short notes and short articles up to a few hundred words are solicited from interested members. This material should be submitted to Gary E. Melickian, c/o Dames & Moore, 816 West Fifth Street, Los Angeles, California 90017.

Grading Code Development in Los Angeles

Southern California has experienced rapid growth. Through the 40's, much of this growth was in the relatively "flat" land. Hillside development was at a minimum. Houses in the mountainous areas were generally custom-designed and built. Since the late 40's, the population has grown rapidly. With this growth, the hillsides have been extensively graded and developed for living space. The local public became acutely aware of a wide variety of geologic problems such as erosion, flooding, landslides, creep, expansive soils, and so forth.

During the 1951-1952 storm season, the rainfall measurement in the center of Los Angeles was seven inches in six days. This was sufficient to create a number of failures. Total damage was estimated at $7, 500, 000. These were generally a result of failure to remove brush and unconsolidated natural soils below fills, lack of proper compaction, daylighting of sedimentary rock, uncontrolled water runoff, and addition of water through septic tanks, cesspools, and heavy irrigation. Based on the evaluation of these failures, the City, in 1952, first began to require geologic reports prior to hillside construction. The first grading code was also set up by the City in 1952. Essentially, the grading code required thorough investigations by soil engineers and engineering geologists. Since then, about 15 southern California cities and several counties have developed grading codes and geologic reports have been required by more and more public bodies.

In 1958, the city of Los Angeles set up a qualification board for registering engineering geologists. Subsequently, only geologists registered with the City could submit engineering geologic reports on hillside development. Similar qualification boards were set up in Los Angeles County in 1960 and in Orange County in 1962.

The first test of the City grading code was in January 1956. At that time 8 inches of rain fell in 36 hours. The rain caused certain types of damage which resulted in three ordinance changes. These changes were as follows:

1. Many bedding plane slides were encountered during the slides. Thereafter, 45 degrees was the maximum slope of any cut, regardless of the geology.

2. Fill surfaces frequently failed. An ordinance change requiring the rolling of fill slopes was developed.

3. The third change was the requirement of a ten-foot space between the end of a house and the toe of a graded slope.

The second test to the City grading code was during the 1957-58 storm year when several months of low-intensity rainfall occurred. The soils became extremely saturated. At that time, the Pacific Palisades area was very badly hit. However, the low-intensity rainfall for a long period of time did not seem to affect the fill slopes and it was felt that the surface rolling requirement was satisfactory.

Finally, the City grading ordinance was tested again in the 1961-62 storm season. Eight inches of rain fell in seven days. However, although the total amount of rain was similar to that which had fallen in 1951-52, the damage in 1961-62 was approximately one-third to one-fourth of $7,500,000 even though there were many more buildings in the hillside areas. The storms of 1961-62 brought to light some specific needs on the part of the ordinance. Three conclusions seemed to be appropriate:

1. Fills constructed under the ordinance did not undergo arcuate failure.
2. Bedding plane slides were now infrequent for construction which had occurred since the 1956 modification to the code.
3. Erosion control seemed to be generally effective.

However, other problems became apparent. The most frequent was the shallow failure of compacted fills. Ninety per cent of the 1961-62 failures were of this type. It became apparent that the slope rolling restrictions could not handle a higher intensity rainfall, although it was fairly effective for prolonged low-intensity rainfall.

Although it was felt that the erosion control and drainage provisions of the code were adequate from the design standpoint, maintenance became a problem. For instance, drains on berms plugged up and water overflowed down the hill slopes. In some cases, owners had interfered with the drainages by planting or dumping weeds over the sides. Finally, there appeared to be some deep-seated arcuate failures in rock cut slopes.

Based on the 1961-62 experience, the City again modified the code to accomplish the following:

1. More adequate mapping of fault zones and location of subsurface water.
2. Exposure of the hard inner core of a fill. In such cases, the area is overfilled and then cut back about 18 to 24 inches.
3. Closer spaced drains and benches, both vertically and horizontally.
4. Widened drainage benches.
5. Landowners to be made more cognizant of maintenance problems; to be educated to maintain the drainage systems and slopes.
6. Deeper drillings to investigate potential deep arcuate failure in rock.
7. Geologic investigations to be "beefed up" to satisfy the City Department of Building and Safety.

The current City grading ordinance was passed in 1963 as the result of the '61-62 experience. This is the most restrictive ordinance ever passed. At the present time, construction under this new ordinance has not been going on long enough to test the adequacy. Based on the historical record, I feel that it may not be possible to develop a grading code which can "solve all problems" in hillside construction. As this is attempted, a code may become too restrictive to permit innovation or a different approach to engineering and geologic problems.

published an excellent summary of the problems related to hillside development. Included within this guidebook is a table listing all of the grading ordinances in California and designating the code requirements as to fill slopes, cut slopes, requirements for geologic reports, compaction requirements, and so forth. All engineering geologists interested in hillside development and urban planning are encouraged to purchase this publication through the Los Angeles Section of the AEG. The cost is $2.00. Letters should be addressed to: Los Angeles Section, Association of Engineering Geologists, P. O. Box 4215, Glendale, California 91202.

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ENGINEERING GEOLOGY IN CONSTRUCTION OF THE NATIONAL ROAD - 1825

George W. White

Engineering geology is a relatively new term, but the connection of engineers and geology is very ancient, as shown by the great canal engineers Vitruvius, Leonardo da Vinci, and William Smith, "the father of stratigraphic geology". The way in which geology was taken into account in canal building would be a monographic study for a historian of geology and of technology. It is also known that geology was taken into account in the building of turnpikes and other great new roads of the early United States. The kinds of geologic information used in planning and construction of a part of the famous National Road, which eventually ran from Cumberland, Maryland to St. Louis, are illustrated in a 32 page report, House of Representatives, War Dept. Document No. 51, 19th Congress, First Session; Road from Wheeling to Missouri. . . . . report of the chief engineer in relation to the survey, location , and progress of the road from the right bank of the Ohio, opposite to Wheeling, to the state of Missouri, Washington: 1826. This report actually deals only with that part in Ohio from Bridgeport, opposite Wheeling, to Columbus, of the road always called the "National Road" or "National Pike", and much later to become U. S. Highway 40.

Major General Alex. Macomb, Chief Engineer, U. S. Army, transmitted to Secretary of War James Barbour copies of the correspondence with Jonathan Knight, Commissioner for the Continuation of the Cumberland Road, and with Caspar W. Wever, Superintendent of the Road, together with the reports of the commissioner and superintendent. In this present day of elaborate instructions couched in legal phraseology it is refreshing to read the simple instructions to Knight and Wever to build a road from the Ohio River to Columbus.

Jonathan Knight (1787-1858) was already known in 1825 as a competent civil engineer and was later to be known as "one of the notable engineers of his time" (Dict. Am. Biog.). In letters of March 29 and March 30, 1825, covering less than three printed pages, General Macomb instructed Knight to review the preliminary location from Wheeling to Zanesville, change the route if he thought advisable, locate a route from Zanesville to Columbus and thence to Indianapolis, Vandalia (Illinois) and St. Louis. The Commissioner was to receive $6.00, each surveyor $3.00, and each other necessary assistant $1.00 per day. To defray "the expense of surveying and marking the road" $10,000 was appropriated and Knight was instructed to draw on the department for required sums using "due economy".

Knight was also instructed, on the plat of the road he was to submit, to "designate the hills and mountains, towns, villages, and settlements;also, the rivers, runs, marshes, woods and rocks, and any other remarkable objects......The quality of the stones or rocks, as well as of the soil, will demand your particular notice and examination. You will also state whether there is....the proper materials for making permanent roads, to be found on the route, or near enough to be applied for that purpose......It is unnecessary to be more particular, having entire confidence in your abilities to execute the same." In other words -- "build the road".

The route was to be cleared for a width of 80 feet. The road bed was to be 30 feet with "hills to be cut down, the earth,rocks and stumps removed". The cuts and fills were to be such that no grade was to be greater than four degrees. On the fills the sides were to slope not exceeding 30 degrees and proper allowance was to be made for settling in the fills and "no stumps, logs or wood of any kind be permitted in the filling". In necessary places "side walls must be built for sustaining the earth" where the "nature of the ground" would require. Special precautions were to be taken to prevent "the earth from falling or slipping" in cuts and fills. The roadway was to be carefully drained by sufficient ditches. The surface was to be "covered 20 feet in width with stone broken into pieces weighing not more than 4 ounces". The first layer of stone was to be 3 inches, and "no stones to be used but such as hard or granite, flint or limestone". An additional cover of 3 inches was to be put on in the following year, but it appears the engineers were allowed to use their own judgment about the time of the second layer. The road was to be made according to the principles of McAdam "that you are particularly referred to".

The instructions further stated that "all the masonry must be executed in the best manner, that is, durable in character, not extravagant in embellishment, but plain and strong and of the best materials". Particular attention was to be paid to the mortar. It appears that General Macomb had been informed that careless mixing of mortar and even use of clay was characteristic of the frontier.It appears that Mr. Wever examined the ground in the next few weeks and wished to modify the instructions for one three-inch layer of stone now and another after a year to two three-inch layers immediately. General Macomb informed Mr. Wever that he would like to have a fair trial of the original instructions, but "after the first year three inches more will be put on and if that quantity does not answer three inches more the next year, which will give nine inches and so on and so on, until the road shall have attained a complete and impervious cover". No doubt Mr. Wever was correct, because over half of the route from the Ohio River to Zanesville lies upon Pennsylvanian Conemaugh rocks, which include much fine-grained shale and the resulting clay loam soils;three inches of crushed stone is not sufficient for a road bed on these soils.

Within the following few weeks Knight and Wever had decided between two alternate routes, choosing the more direct one through Fairview rather than a more southerly one through Barnesville. Although they had been instructed to let the contracts in two mile or larger units they actually let the contracts for units as little as one-half mile in length. One reason for doing so was that if larger units were let, only a few people could bid and these would then proceed to let smaller units to sub-contractors, so it was decided to let the routes directly to those who would otherwise be sub-contractors. Another reason was that "each section would include throughout ground as nearly alike as possible", so that estimation and bidding could be more precise, thus saving money.

The final seven pages of the little document is a "Memoir" which is the interim report of Commissioner Knight to December 22, 1825. It is in this report that we discover much of the geological reasoning used by Knight and Wever in the location and construction of the road. The route from the Ohio River to Zanesville was over the unglaciated Allegheny Plateau with a relief of several hundred feet. The route, consistent with directness, generally followed the ridges. Where it followed favorably situated valleys it was cleverly located far enough above the streams to be generally above flood level. It was recognized that the route westward from Zanesville to Columbus presented more variety: "As we proceed from Zanesville, the country, for the first seven miles, is literally cut up with drains and tributaries .... West of that for about thirteen miles, the country is uneven...... The hills thus formed, are not so high as those east of Zanesville, but they are, if possible, more irregular." The hills terminated 20 miles west of Zanesville and "west of the termination of the hills....... the ground to be surveyed" was on the "Great Plain" which continued far beyond Columbus. Knight took into account these changes in topography, relief and soils, but of course did not realize their cause. The boundary of the Illinoian glacial drift runs approximately north-south about 7 miles west of Zanesville and the 13 mile wide area of Illinoian drift consists of more rounded bedrock hills than those in the unglaciated area to the east. Also other "irregular hills" (kames) in the Illinoian tract required unusually detailed exploration of alternate routes in order to find the most suitable one.

Twenty miles west of Zanesville is the very sharp and noticeable Wisconsin glacial boundary which almost coincides with one of the escarpments of the plateau, to the west of which the rocks are Mississippian shales and siltstones, with very little real sandstone. From this point on it was noted that the main problem in location would be to avoid the swamps, particularly the large one which was later flooded to become Buckeye Lake, and to find suitable places to cross several of the major north-south streams tributary to the Scioto River, whose floodplains were incised below the level of the plains. Particular attention was paid to the materials for constructing the road: "Throughout the hilly country, good materials are convenient and abundant for the mason work. For the metal or paving of the road, not so much so. There is plenty of sandstone; but this description should only be used where limestone, or freestone of a hard quality, cannot be procured under reasonable expense." There was indeed sufficient sandstone for dimension stone located close to the road from Wheeling to Zanesville. Some of the beautiful sandstone bridges still remain in roadside parks or near the now relocated U. S. Highway 40, attesting to the skill in design and construction from local stone. Limestone and "freestone" were reasonably available for road metal.

West of Zanesville it was stated that "stone can be had in sufficient abundance....... (for)....... a distance of 20 1/4 miles, after which, stone becomes very scarce and the mason work is rated accordingly". This was the area of Mississippian shale and thick glacial drift. Knight noted that outcrops of sandstone were many miles away from the route and in a restricted quantity, but that in the Scioto valley at Columbus, limestone (Devonian) would be available. It was therefore recommended "that the remainder of the road to Columbus (that is beginning 20 miles west of Zanesville) be not stoned, but gravelled", because gravel is available throughout this area. Indeed, it was discovered that "about three miles of the route, between the system of swamps in the south fork of the licking", the road would pass "on a sub-stratum of clay about one foot deep and underneath it gravel. Here the grading of the road would also gravel it". In other places it was thought that gravel could be found within a distance of not more than two miles. They clearly recognized the vast quantity of gravel although they had no idea that its origin was glacial.

The material for bridge construction was taken into account; the bridges in the hilly part were "near to good rock. They are estimated to be constructed altogether of stone." On the route from 20 miles west of Zanesville to Columbus, "where rock is scarce", it was suggested that the bridges "be constructed of stone underneath and a superstructure of wood to be weather-boarded and roofed for preservation from decay". Such construction was successful -- one of the largest of these covered bridges, at Hebron, in use for more than one hundred years, testified to the satisfactory structure of the abutments on rather difficult foundations.

It is apparent from reading the documents that Knight, the Commissioner, and Wever, the Superintendent, worked harmoniously together and that each had the complete confidence and respect of the other. They used the latitude and discretion allotted them and they unquestionably selected the best route and made the best use of local materials in construction. They had examined the character of the soil and the possible construction materials far enough in advance so that the road building could proceed expeditiously. Thus, the greatest road of the young Republic was brought to quick completion and became an important factor in the development of the western country.

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E D U C A T I O N

UN Program in Applied Geology

Dr. Carl Tolman has just undertaken a position with the United Nations Development Program in the Philippines as Project Manager in the establishment of a quality program in Applied Geology for the training of educators and geologists from industry. At present this program includes structural geology, economic geology, geophysics, and geochemistry. The one gap in the program which it is hoped may be filled is in Engineering Geology applied to Civil Engineering projects.

Dr. Tolman may be remembered for having set up, at Washington University (St. Louis), the first accredited curriculum and program in Geological Engineering in 1948. Dr. Tolman was also formerly Chancellor of Washington University at St. Louis and more recently attaché at the U. S. Embassy in Tokyo.

Continuing Education

One hundred forty-five engineers and geologists participated in the one week course in Geological Engineering conducted during August at the University of California, Berkeley. They came from 25 states and 4 foreign countries. The course was most heavily supported by governmental agencies and private consulting firms in the water and power fields. The success of this course testifies to the growing involvement of engineering organizations in matters related to geology.

CONFERENCES AND ACTIVITIES OF SOCIETIES

R. E. Goodman

Inter Society Committee on Rock Mechanics

Cooperation between societies involved in the field of rock mechanics is a reality. If ratified, the newly adopted by-laws will make GSA and AEG charter members of the Inter Society Committee on Rock Mechanics along with ASTM, HRB, ASCE, AIME, SPE, SSA, AGU, SME, and SEG. The Committee has agreed to sponsor annual meetings on rock mechanics to be hosted by universities active in this field throughout the country. Beginning in 1968 the ICRM conference, building on the five school annual symposia on rock mechanics, will strive to be the meeting to attend if you are interested in the latest results in the broad interdisciplinary aspects of rock mechanics.

First Congress of the International Society of Rock Mechanics; Lisbon, September 25 to October 1, 1966

Advanced Proceedings of this enormous Conference were distributed to participants in early September. Volume I includes reports on exploration, description, and properties of rock masses while Volume II deals with residual stresses, comminution, slopes, underground excavations, and foundations. The 241 contributions total 1462 pages and almost all of it is of interest to engineering geologists.

Conference on Economic Geology in Massachusetts

Contributed by O. C. Farquhar

A three-day Conference on Economic Geology in Massachusetts was held at the University of Massachusetts in January 1966. Many of the papers dealt with engineering and applied subjects, the eight sessions covering bedrock and surficial geology, industrial rocks, geomechanics, mineral resources, geologic aspects of construction, geophysics, ground and surface water, and the shoreline and the ocean. Papers were given on the Geology of the Cape Cod National Seashore (Joseph H. Hartshorn), Greater Boston urban geology (Clifford A. Kaye), the Littleville dam (Robert C. Gurley), the New Bedford hurricane barrier (Carl G. Hard), the planned Northfield Mountain pumped storage hydro project (John R. Rand; also William Swiger), possible use of tunnels for high-speed transportation (Ronald C. Hirschfeld), the Wachusett-Marlboro tunnel (Rev. James W. Skehan, S. J.), bedrock studies in west-central Massachusetts (Peter Robinson), mineral occurrences (Alonzo W. Quinn; Newton E. Chute; Duncan G. Ogden; and others), slumped Triassic sedimentary rocks (O. C. Farquhar), preliminary results of aeromagnetic surveys (Randolph W. Bromery), and Use of air photos (H. T. U. Smith), in addition to discussions of profiling in Boston Harbor, the state's earthquake history, bridge foundations, granite and crushed stone, erosion control, and land valuation.
Specific topics dealing with water resources in Massachusetts included: seismic surveys for ground water investigations (Vincent J. Murphy and Thomas F. Sexton), the U. S. Geological Survey ground water program (R. G. Petersen), ground water in the Connecticut Valley (D. J. Cederstrom), geology in the search for ground water (Paul F. Howard), surface water (C. E. Knox), and rock chemistry in water quality control (Angelo Iantosca).

More than 60 speakers took part, and some 350 people attended the conference, which was planned to show how geological activities in Massachusetts are being used to solve a variety of important problems. While the great majority of states possess a geological division within the government organization, Massachusetts is almost alone in having no such focus for application of the geological sciences. The discussions at this conference resulted mainly from work conducted by consultants, federal agencies, and universities.

Introductory remarks were given by Marland P. Billings of Harvard University (who also spoke on the significance of faults in tunnels), and the role of the U. S. Geological Survey in Massachusetts geology was described by Lincoln R. Page, Chief, Branch of Regional Geology in New England. John G. Broughton, New York State Geologist, discussed "The State Geological Survey - the special role of a generalist", and Charles H. W. Foster, then Commissioner of the Massachusetts Department of Natural Resources, traced the growth of that agency. One of the purposes of the conference was to present work of intrinsic interest: the general theme was the possibility of establishing a state bureau to expand geological services in Massachusetts. The conference was arranged by O. C. Farquhar, Department of Geology, University of Massachusetts, who submitted this report.

Symposium on Shale - Sponsored by GSA/ASCE Joint Committee on Engineering Geology. Contributed by T. H. Thornburn.

A Symposium on Shale, arranged by S. S. Philbrick, was held in conjunction with the Water Resources Conference of ASCE in Denver last May. The Symposium opened with an all-day field trip on May 16, which was arranged and presented under the leadership of Glenn R. Scott and Robert M. Lindvall of the U. S. Geological Survey and Harold W. Kirchen of the U. S. Bureau of Reclamation. During the trip various exposures of shale in the vicinity of Denver were inspected and at each site the trip leaders led a discussion on the general characteristics of the shale and its typical engineering problems.

The field trip was followed by two half-day sessions May 17 and 18. The first session was devoted primarily to discussion of the physical properties of shale in conjunction with their classification, nomenclature and identification, while the second session was devoted primarily to the discussion of engineering problems in shales. Papers given in Session 1 were: Definition of Problems of Shales by Shailer S. Philbrick; Classification, Nomenclature and Identification of Shales by L. B. Underwood; Physical Properties of Shale by Frank M. Mellinger; Shale Mylonite -- Some Remarks regarding its Occurrence and Shear Strength by Don U. Deere, R. B. Peck, and Shailer S. Philbrick; and Excavation Methods in Shales by Charles S. Content. The following papers were presented in Session 2: Planning Slopes in Shale and other Rocks by Donald F. Coates; Foundation Rebound and Settlement -- Dos Amigos Pumping Plant by John P. Bara and Roland R. Hill; Effect of Predicted Foundation Movement on Design of Dos Amigos Pumping Plant by George Evans; and Clay Shales in Earth Embankments by W. A. Clevenger.

Both sessions of the symposium were very well attended and there is no doubt that a number of significant papers will be forthcoming in the Journal of the Soil Mechanics and Foundations Division as the result of the accumulation of the information presented here.

ACTIVITIES OF ENGINEERING GEOLOGISTS

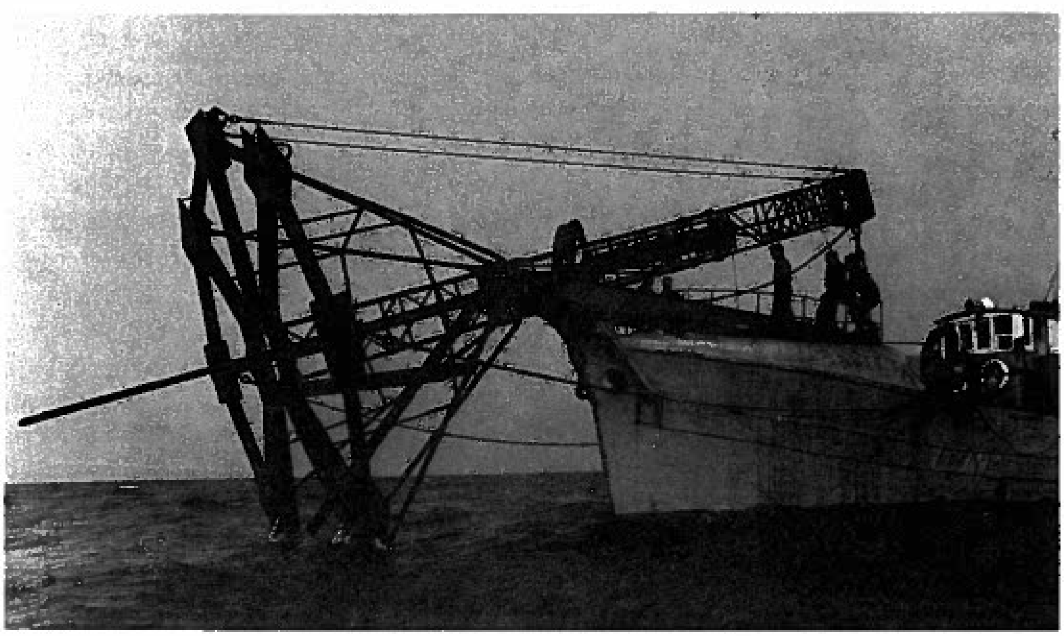
Arthur Cleaves

Professor Alfred Falconnier, Nyon, Switzerland, who, with Arthur B. Cleaves is still connected with the consulting work in Peru on the Mantaro hydroelectric project, is one of the busiest geological engineers in Switzerland. He does a considerable amount of consulting for the World Bank. This past year he has spent most of his time on projects in Switzerland, Turkey and Spain.

Dr. Richard A. Young, Graduate of Cornell, Ph. D. Washington University (St. Louis) 1966, has been appointed Assistant Professor of Geology at the State University of New York, Geneseo. This summer he has been working for Ocean Science and Engineering as an engineering geologist in Viet Nam. The company has a contract with the Navy so Dick has been hunting for rock aggregates. The Marines provide helicopter service which has seen Dick into many ticklish areas. He writes that in too many places the best rock occurs in hills upon which Buddhist pagodas stand.

Lynn A. Brown, having completed all of his residence requirements for a Ph. D. at the Colorado School of Mines, has joined the teaching staff in the Department of Geology at Purdue University, Lafayette, Indiana. He will be remembered on the West Coast for the years he spent as a geologist with the Bechtel Corporation.

R. W. Karpinski, who has recently returned from a six months sabbatical in Western Europe, reports that one of the most interesting projects which he visited was the recently opened tidal power installation at Baie de la Rance located in the general Saint Michel Bay area of northwestern France between Brittany and Normandy. Elechicité de France was the client for this project.
The project completed this summer involves a useful basin at 13.5 meters above mean sea level having 22 square kilometers surface and containing 184,000,000 cubic meters of water. This reservoir is held by a combination of a lock, the dam with its 24 generating units of 10,000 watts each and 3 transformers of 80,000 watts each at 225,000 volts -- an earthwork section, and a "barrage mobile" (spillway section): section including the lock, 150 meters long; hydroelectric plant, 390 meters, width 53 meters; earthwork (Dique Morte), 175 meters; and spillway (Barrage Mobile), 150 meters.
In the past there were at least 20 flour mills or sawmills in the Rance-Saint Michel area, all of small size. In 1924, five million francs were voted by the government for early feasibility studies. Present plans call for modification of tidal power by pumped storage. Studies were also made of storing compressed air underground as a means of having energy available when needed. The major problem is that the 24 hour, 50 minute tidal cycle does not coincide with the 24 hour power demand period. With the advent of cheaper nuclear power and the continuing lower cost of thermal projects, the feasibility of tidal power is reduced. Furthermore, detailed coriolis studies seem to indicate many more complications to the Saint Michel Bay project than was previously expected. All of this plus the engineering and geologic problems involved have definitely placed the larger project on the shelf.
Several unusual drilling platforms were utilized in carrying out exploration of foundation conditions for both the Rance and Saint Michel cut-off installations. The Ludim (see upper photo on next page)would submerge and rest on the bay floor during drilling. Another, smaller, platform is shown in the lower photograph.



Drilling platforms used to explore submerged foundation area in French tidal power project

NEW BOOKS AND LITERATURE IN ENGINEERING GEOLOGY

Raymond E. Whitla

Coates, D. F.., ROCK MECHANICS PRINCIPLES: Canada Department of Mines and Technical Surveys, Mines Branch Monograph 874, Ottawa, Canada, 338 p., bound, price $5.00. This publication is intended for young engineers and scientists who are entering the field of rock mechanics. It deals with various theories in mechanics and rock properties on an elementary level and emphasizes the application of engineering mechanics to problems of rock failure, particularly those problems encountered in mining.

De Wiest, Roger J. M., GEOHYDROLOGY: John Wiley & Sons, Inc., 605 Third Ave., New York, N. Y. 10016, 366p, 1965, price $10.95. This book is described by the publisher as a practical, quantitive study of ground water movement as it is related to surface hydrology. It derives the laws of ground water movement from the principles of conservation of mass and Darcy's experiment and applies them to hydrogeologic problems of seepage and water with which they are associated.

Hall, Bruce M., LUNAR DEVELOPMENTAL HISTORY AND ITS ENGINEERING IMPLICATIONS: U. S. Army, Office of the Chief of Engineers, Technical Note No. TN 66-201, June 1966. Available from Defense Documentation Center, Building 5, 5010 Duke Street, Alexandria, Virginia 22314. This report was prepared as part of the Department of the Army's research effort aimed at developing its lunar base technology. Detailed descriptions of the moon and of the engineering characteristics of its surface are fundamental to studies of the performance of man and of materials in the lunar environment and of problems of constructing facilities on the moon. In this report, Mr. Hall describes the origin and the development of the moon and the formation of its surface features in accordance with one hypothesis, recognizing that man's knowledge of the moon as yet is based on very little in the way of hard facts and that most of what is accepted about the moon is little more than conjecture. Engineering properties of the lunar surface are postulated for an average marial topographic province.

Kachadoorian, Reuben, EFFECTS OF THE EARTHQUAKE OF MARCH 27, 1964, AT WHITTIER, ALASKA: U. S. Geological Survey Professional Paper 542-B, 21p., 1965 & Coulter, Henry W., and Migliaccio, Ralph R., EFFECTS OF THE EARTHQUAKE OF MARCH 27, 1964, AT VALDEZ, ALASKA: U. S. Geological Survey Professional Paper 542-C, 36 p., 1966, both available from Superintendent of Documents, Washington, D. C. 20402, price $1.25 each. Here are two more in the series of reports being published by the U. S. Geological Survey on the 1964 Alaska Good Friday Earthquake. Notice of the first report in the series appeared in The Engineering Geologist for April 1966. The first of the two reports listed here describes and analyzes damage from subsidence of the land mass, from waves generated by submarine landslides, from fires, and from seismic shock at the port of Whittier, Alaska; the other describes the massive landslides, the destructive sea waves, the landmass displacements, and the extensive ground breakage due to the earthquake at Valdez, Alaska.

Visser, A. D., ELSEVIER'S DICTIONARY OF SOIL MECHANICS - THEORETICAL AND APPLIED: Elsevier Publishing Company, Amsterdam, 359 p., 1965, $20.00. This is one of a series of multilingual technical dictionaries relating to special fields of science and industry that are planned by Elsevier. It contains 4,120 terms and is in four languages, English/American, French, Dutch, and German. The basic table is in English/American and the French, Dutch, and German terms are referenced back to the basic table through alphabetical lists in the other languages in the appendices. The book is intended to be of assistance to all who are interested professionally in soil mechanics.

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Clark, S. P., editor, HANDBOOK OF PHYSICAL CONSTANTS, Revised Edition, GSA Memoir 97, 1966, 583 p., $8.75. This comprehensive reference book will prove as indispensable to workers in quantitative aspects of geology as its forerunner, Special Paper No. 36 by Dr. Francis Birch. Perhaps of greatest interest to engineering geologists are the chapters on density of rocks, thermal expansion, compressibility, internal friction, seismic velocities, strength and ductility, viscosity, and thermal conductivity.

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