



Thompson Describes Determination of Rock Moduli Data for Underground Installations

Thomas F. Thompson

A method for determination of stress and modulus of deformation of a rock mass that is being considered for embedded penstocks or the stability of an underground powerhouse excavation is described as follows by T. F. Thompson, Consulting Geologist.

1. Assuming that diversion of the river for construction is to be by means of tunnels and that the site is within a steep-walled canyon, NX-sized holes are drilled from the ground surface above the tunnel and from the canyon walls on the river side of the future tunnel.

2. The floor and walls of the future tunnel are over-drilled by 3 to 5 feet, bench marks set, and their locations accurately determined. The bench-marks should be set beyond the distance of the effects of blasting needed for tunnel driving.

3. The sections of the bench-mark holes outside of the tunnel neat lines should be backfilled with sand. The sections across the tunnel's diameter should be backfilled with colored sand-cement grout to permit easy identification when tunnel driving encounters the locations of the bench marks.

4. After the tunnel has been driven beyond the crossed lines of the grouted holes, the sand filling should be washed out, and the rebound between the opposite holes measured to determine the strain that has resulted from opening up the space between the opposite holes.

5. From the decrease in distance observed by accurate measurements, the moduli required for the design of the concrete lining and steel shell can be readily computed.

Editor's Note:

Your editor was intrigued by Tom's brief description of the above procedure and wrote asking for more information. Following is Tom's reply.

Your letter of September 8th is referred to.

To determine the horizontal shift of monuments in the holes drilled for determination of moduli under the system which I described in my brief note, I think that the simplest thing to do is attempt to drill an absolutely plumb vertical hole from the surface through the tunnel section. This can be done ordinarily by use of PK rods in an M-size hole.

The procedure which I have used with considerable success is as follows:

1. Drill hole to final depth, which should be below the blast disturbance zone when the tunnel is driven.

2. Set lower monument as follows: The monument should be a steel cylinder of a diameter that will slide easily down the hole. To the bottom of the cylinder should be affixed a bag of epoxy resin cement similar to that put out commercially for rockbolts.

A knife on the bottom of the cylinder will pierce the bag and release the cement when it reaches the bottom of the hole.

3. Having reached the bottom of the hole (lowering the bench mark by means of an invar tape), the knife will release the epoxy, which should be of the quick-set type. After allowing the cement to set, a strain should be taken on the bench-mark using a spring balance to give the desired tension. The invar tape is read by micrometer fingers extending out from the four quadrants of the top of the hole, and this data recorded. The hole is then filled with coarse sand up to the future perimeter line of the tunnel. The hole is then

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Chairman's Column

As my term draws to a close, it is natural to reflect on the accomplishments of the past year. I find that, for an organization, it is not easy to identify and enumerate accomplishments on a short-term basis. However, we can be proud of this newsletter, which is being continued under the Editorship of Lloyd B. Underwood, and our technical sessions at the annual and section meetings, as mediums for periodic dissemination of information and progress in our work. We look forward to more use of the *Bulletin* as a medium for papers and short notes on significant engineering geology projects and developments, and to future issues of the *Case Histories and Review Volumes*.

The strength, prestige, and acceptance of the engineering geologist and of our organization are determined more by the performance of the individual members than by the literature that we generate. Final decisions on engineering geology problems must be based, to a large degree, on personal opinions and judgments, and are proved by the findings during construction and the performance of the final product. In the past thirty years, the number of engineering geologists has increased many times and the acceptance of our advice is now routine in many organizations. This acceptance is recognition of the value of our services. As our ranks grow and the demands for our services increase, we naturally develop tools that reduce leg work and increase our efficiency. As we learn to use these new and sophisticated tools, some of us develop an unwarranted confidence in them and in our ability to make sound interpretations from the data so obtained without taking the time for making detailed investigations and personal inspections of the geologic conditions involved.

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Thompson . . .

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backfilled with colored grout to the level of the future tunnel's crown and with sand to about 1 meter beyond (to place the benchmark beyond possible damage from blasting). A similar procedure is then followed for the upper monument, except that no sand is introduced into the hole. The tape can be left attached to the monument. After the epoxy has set, a similar reading procedure to that performed for the first measurement is followed.

4. When the tunnel passes the grout column it is readily recognized, and the measurements between the base of the upper monument and the lower one can be made from the drill jumbo. The lower monument can be washed out by means of a pressure hose. It may be necessary to trim both holes to enable accurate measurement between the two benches. The distance between the point of attachment and the bottom of the upper monument should have been accurately measured before the upper one is set in the hole. While this has sufficed in the cases with which I have been associated, it may be possible to use a laser beam to locate the exact position of the lower and upper points if horizontal shift data is desired as they are placed in, and later to repeat the process which would give the "shift" information. I have never tried this. In the case of holes drilled in from the sides of a canyon, the use of drill rods or a pipe is required to insert the monuments. A packer may be used in this case to contain the epoxy below the top of the steel cylinder used for the bench mark. By using a multiple system of holes crossing the future tunnel, the direction of shift and amount can be determined. This system has been employed on three projects with which I am associated, and I believe gives more dependable results than the conventional overdrilling or flat-jack tests.

Thomas F. Thompson
Consulting Geologist

Editor's Note:

It is hoped that the readers of The Engineering Geologist will feel free, from time to time, to send in a brief description of new techniques or procedures they have developed that might be of interest to fellow engineering geologists and the profession as a whole.

Army Corps of Engineers Has New Chief Geologist

Gordon W. Prescott has been appointed Chief of the Geology Branch in the Engineering Division of the Directorate of Civil Works, Office of the Chief of Engineers, and chief geologist for the U. S. Army Corps of Engineers effective 13 April 1969. He has served as assistant chief geologist for the past 12 years. As Chief of the Geology Branch, he will be chief technical advisor in the field of engineering geology on the design and construction of all flood-control, navigation, and hydro-power structures of the Corps of Engineers, and will have over-all supervision of engineering geology and rock mechanics research in the Corps of Engineers' laboratories.

Prescott's career, before coming to the Office of the Chief of Engineers, included employment with the consulting firm of Carl Bays and Associates, the U. S. Army Corps of Engineers in its former Garrison District, the Illinois Geological Survey, and the Halliburton Company.

Gordon Prescott holds a Bachelor of Science degree from North Dakota State College, Fargo, North Dakota, and he attended graduate school at Washington University in St. Louis, Missouri. He is a fellow of the Geological Society of America and Program Committee Chairman for Engineering Geology Division for the meeting this fall in Atlantic City. Mr. Prescott also is a member of the American Association of Petroleum Geologists and of the Geological Society of Washington. He is a registered professional engineer in the state of Illinois

Hardeman Announced New Chief Geologist, TVA Resources Branch

The Tennessee Valley Authority announced recently that W. Hardeman, State Geologist of Tennessee, will succeed Berlen C. Money maker as Chief Geologist of TVA, upon Money maker's retirement next September. Mr. Money maker has been Chief Geologist of TVA since 1942, when he succeeded the late Major Edwin C. Eckel, TVA's first Chief Geologist. Hardeman has submitted his resignation and will join TVA's staff about June 1.

As presently constituted, TVA's Geology Branch has two Sections, Engineering Geology (John M. Kellberg, head) and Mineral Resources (Robert W. Johnson, Jr., head). It is speculated with the appointment of Hardeman that TVA may emphasize and possibly expand their resources studies.

As engineering geologists, in a field which TVA was a pioneering organization, we hope that engineering geology is not relegated to play "second fiddle"; however, since TVA is still involved in a number of construction projects, site explorations for new projects and in monitoring the foundation behavior of previously constructed dams, we are certain it will need its engineering geologists for many years to come.

Nominations Now Open For E. B. Burwell, Jr., Memorial Award

The E. B. Burwell, Jr., Memorial Award of the Engineering Geology Division is made to the author or authors of a published paper of distinction which advances knowledge concerning principles or practice of engineering geology or of the related fields of applied soil or rock mechanics where the role of geology is emphasized. Although the paper shall have been published not more than five years prior to its selection, there is no restriction as to the publisher or publishing agency. The author or authors of the selected paper need not be a member or members of the Engineering Geology Division or of The Geological Society of America and need not be residents or citizens of the United States. A certificate and cash award will be presented to the recipient at the annual Engineering Geology Division luncheon.

The recipient of the award is selected by a six-member committee appointed by the Management Board of the division; however, any member of the division may nominate a paper or papers for consideration by the Award Committee by sending the name of the nominee, the title of the paper and its publication source not later than January 15, 1970, to the secretary of the division, Richard E. Gray, c/o General Analytics, Inc., 570 Beatty Road, Monroeville, Pennsylvania 15146.

THE ENGINEERING GEOLOGIST

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THE ENGINEERING GEOLOGIST is issued by THE GEOLOGICAL SOCIETY OF AMERICA, Engineering Geology Division, P.O. Box 1719 Boulder, Colorado 80302.

SAFETY AND EFFICIENCY DICTATE USE OF MATERIAL FOR CORROSION CONTROL AT CONSTRUCTION OF WORLD TRADE CENTER

A unique, continuous length zinc anode material has been used to provide the Port of New York Authority with a five-year insurance policy on the vital tie-back tendons that support the massive perimeter wall surrounding the westerly portion of the World Trade Center site. The material, Diamond Line Continuous Length Zinc Anode, was developed by American Smelting and Refining Company's Federated Metals Division to provide low-cost corrosion protection for steel in a wide range of marine and underground installations. Approximately 20 miles (more than 100,000 feet) of the ribbon anode material has been used on the World Trade Center project.

The lower Manhattan site, which is encompassed by the perimeter wall, represents the area of the deep foundations for the Center's two 110-story Tower Buildings and measures some 600 feet in width and 1,100 feet in length.

Must Withstand 5,000 psi

Excavation for the wall averages 65 feet in depth to bedrock, with pressures at the bottom of the wall exceeding 5,000 pounds per square inch. The perimeter barrier is designed to seal off water and loose soil from the future basement areas. According to the Port Authority, the water level in this area reaches to one foot below the earth's surface, which accounts for the tremendous amount of pressure the wall must be able to stand.

For this reason, the perimeter wall was built of reinforced concrete, three feet thick, and supported laterally by 1,500 tie-back stress tendons, which are anchored into the bedrock 65 feet below ground level. The tie-backs are temporary and will be cut when permanent floors provide the necessary support.



Workers prepare to lower tie-back system through channel in perimeter wall for fastening into bedrock below.

Safety Factor Cited

In choosing Diamond Line to protect the perimeter wall tie-backs, the Port Authority had to consider a number of difficult problems. "Since the tie-backs are temporary installations, we were naturally concerned with holding down costs. Nevertheless, because of the safety factor involved, we had to be certain that whatever we decided to use would provide full corrosion protection for the life of the installation," E. R. Kennedy, Engineer of Materials Research for the Port Authority, explained.

The tie-back tendons consist of high-strength wires having an approximate diameter of 0.165-in. (270,000 psi minimum ultimate strength), with an allowable design stress of 175,000 psi. The high unit stress required in the small wires creates a sensitivity to loss of metal through corrosion. This loss is prevented by the use of Diamond Line.

Selection of the right corrosion system for the job was assigned to Leon P. Sudrabin, a Berkeley Heights, N. J.-based professional engineer and corrosion consultant who conducted a series of tests to determine the corrosion situation on the proposed tie-backs in the Trade Center area. According to Mr. Sudrabin: "We began our investigations in the summer of 1965 by setting up a test site on West Street. We drilled a pilot hole and had a tendon assembly made up and installed with grout. At the same time, we took potential measurements of the area and studied cored samples of soil. Our tests clearly revealed the presence of stray currents flowing from southwest to northeast in the area. These currents originate in subways and power stations located throughout lower Manhattan.

"We also found that the water table with which we would have to contend was made up of brackish salt water, and that the land fill in and around the World Trade Center site was composed of a variety of low-resistivity soils."

The result of these tests confirmed the need for a ribbon anode system which provides continuous protection along the entire length of the tie-backs. Of primary importance, any anode system used would have to have a low driving voltage adequate to provide full corrosion control, and yet be able to guard against the possible formation of hydrogen on steel tendons which could contribute to hydrogen stress cracking.

Designed 'Into' Tie-back System

"We were also seeking a system that could be used as an integral part of the anchoring system." Mr. Sudrabin said, "In other words, it would have to complement the design of the tie-backs in order to make final installation as easy and as inexpensive as possible."



The site of The World Trade Center, including engineer's conception of perimeter wall (1) with tie-backs (2) in place.

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New Books and Literature In Engineering Geology

Raymond E. Whitla

Blanc, Robert P., and Cleveland, George B., **NATURAL SLOPE STABILITY AS RELATED TO GEOLOGY, SAN CLEMENTE AREA, ORANGE AND SAN DIEGO COUNTIES, CALIFORNIA:** California Division of Mines and Geology, Special Paper 98. 19 pp., 1968. Available from California Division of Mines and Geology, Ferry Building, San Francisco, California 94111. Price \$2.00. This study was initiated to evaluate the stability of natural slopes by determining the causes of landslides and to present the data on natural slope stability in a form readily usable for broad scale urban planning. A significant part of urban growth in southern California has developed radially from population centers in the flat-lying lowland areas into the highlands where geologic features and processes have considerable influence on the stability of the surface and on the cost of engineering works. The City of San Clemente was developed mainly on flat-lying marine terraces but has expanded in recent years onto the hillsides. The hillsides are mantled with numerous old landslides. The report discusses some of the general considerations in assessing slope stability, the landslides in the San Clemente area and their origin, and the interpretation of natural slope stability. The interpretation of slope stability control is shown on a series of maps, each map pointing out lithologic, structural, or geomorphic conditions that are indicative of unstable or potentially unstable slopes. A slope stability map in the pocket at the back of the report combines the data presented on each of the other maps along with additional information to provide a single analysis of the region. The map is intended for broad-scale terrain evaluation, though, and not for the planning of specific engineering projects.

Brawner, C. O., **THREE BIG FACTORS IN STABLE SLOPE DESIGN:** Mining Engineering, vol. 21, no. 8, pp. 73-77, August 1969. Although this paper was intended as a discussion of factors influencing slope stability in open-pit mines, it is applicable to any open-cut excavation. The author recognizes that many factors influence slope stability in rock cuts. In this paper, though, the discussion is confined to rock structure, groundwater, and blasting. The paper describes briefly how these factors influence slope stability, methods of determining what the rock conditions are insofar as these factors are concerned, and what might be done to produce stable slopes.

Ward, W. H., Burland, J. B., and Gallois, R. W., **GEOTECHNICAL ASSESSMENT OF A SITE AT MUNDFORD, NORFOLK, FOR A LARGE PROTON ACCELERATOR:** Géotechnique, vol. 18, no. 4, pp. 399-431, December 1968. This paper describes how the suitability of a site on Middle Chalk near Mundford in Norfolk, England, was assessed as a possible site for construction of a giant proton accelerator that is to be built by the European Organization for Nuclear Research to meet European needs for nuclear research in the remaining years of this century. This machine is rated at 300 GeV, or about ten times more powerful than the organization's existing machine in Geneva, Switzerland. The Government of the United Kingdom has offered the site near Mundford as a possible site for construction of the accelerator. The machine will consist of three main components: the main accelerator, its tangential beams, and the experimental areas. The main accelerator will have the form of a horizontal underground ring 2.4 kilometers (about 1.5 miles) in diameter to be constructed as a tunnel approximately 5 by 5 meters (about 16.4 by 16.4 feet) in cross section. Some five tangential beam tunnels about 2 to 4 kilometers (about 1.25 to 2.5 miles) long will emerge from the ring and terminate in experimental areas at ground level. All tunnels will need to be buried at least 10 meters (32.8 feet) in the ground for purposes of shielding radiation, and, where the topo-

graphy is such that this is not possible, the tunnels will need to be covered with wide embankments to provide equivalent protection. Some very exacting limits were laid down regarding the natural stability and the load-deformation properties of the ground in which this machine will be constructed. For example, the adopted criterion to be met by the foundation for the shielding of the experimental areas is that vertical displacement of the ground surface at a distance of 50 meters (about 164 feet) from a surface shielding load of 10,000 tons applied over a square area at a uniform load density of 4 kilograms per square centimeter (about 57 pounds per square inch, or about 4.3 tons per square foot) should not exceed 0.5 millimeter (about 0.02 inch). Investigations to determine the load deformation properties of the chalk consisted in examining and classifying the chalk in situ by means of mansize auger holes, in performing a full-scale tank-loading test, and in performing plate-loading tests. The paper describes the geology of the site and gives an engineering classification of the chalk derived from the examination of the chalk in place. It also describes in detail the loading tests that were made and discusses the results obtained from them. It concludes that the geotechnical investigation yielded a detailed picture of the geology and of the engineering properties of the rock at this large site and, from this information, it was possible to show that the site meets the exacting requirements for the proposed accelerator.

Kiersch, George A., and Cleaves, Arthur B., editors, **LEGAL ASPECTS OF GEOLOGY IN ENGINEERING PRACTICE:** Engineering Geology Case Histories No. 7, 112 pp., 1969. Available from The Geological Society of America, P. O. Box 1719, Boulder, Colorado 80302. Price \$3.75. Although this publication was listed in a previous issue of *The Engineering Geologist*, it was not reviewed nor was any mention made of its contents. Engineering geologists are becoming increasingly involved with court cases and the legal solutions to problems and disputes in engineering practice, but little has been published in the geologic literature or in the literature generally available to geologists concerning this aspect of their profession. This publication contains 10 papers that deal with legal solutions to problems in which geology is or was involved. The first of these, by George Kiersch, presents guidelines for the geologists as an expert witness. The other papers deal with legal problems and court cases involving changed conditions, construction claims, vibrations from blasting, ground water, landslides, and land condemnation. These papers indicate the wide range of types of legal disputes in which geology is concerned. Every engineering geologist should have this publication.

Randolph, J. R., Baker, N. M., and Deike, R. G., **BIBLIOGRAPHY OF HYDROLOGY OF THE UNITED STATES AND CANADA, 1964:** U. S. Geological Survey Water-Supply Paper 1864, 232 pp. 1969. Available from the Superintendent of Documents, Washington, D.C. 20402. Price \$1.00. This volume lists references to books, journal articles, and other publications in the field of hydrology published in the United States and Canada during 1964. In addition, some references have been taken from international journals in which American authors frequently publish. For the purpose of this bibliography, hydrology is defined as the science that relates to the waters of the earth, their occurrence, distribution, movement, and chemical and physical properties. All-in-all, the bibliography cites 2,198 references.

WELLPOINTS KEEP BART STATION DRY, *Western Construction*, vol. 44, no. 8, pp. 39-41, August 1969. Construction of the Bay Area Rapid Transit (BART) stations in San Francisco presents some interesting unwatering problems. This article describes the unwatering problem and how it is being met on the Civic Center Station. The Civic Center Station will be 740 feet long by 60 feet wide, enclosed by a 36-inch-thick soldier pile tremie concrete wall. The mezzanine level will extend 20 feet outward from the main station, and the entrance locations will be shored with a 24-inch-thick soldier pile tremie concrete wall. The floor of the mezzanine will be at an average depth of 26 feet below ground surface, and the lowest point of excavation for the

New Books . . .

bottom slab of the main station is 78 feet below ground surface. Excavation is in alternating sand and clay layers. Ground water is encountered at 13 to 20 feet below the surface. Criteria for unwatering and pressure relief require the water level to be maintained 15 feet below the excavation level, and relief of excess hydrostatic uplift to be provided to a depth of 30 feet below the excavation level. On the other hand, water must be added continuously outside the station to keep the water table from dropping as a result of the inside pumping. The article discusses the unwatering system and the ground-water recharge system including the treatment of the recharge water.

PRELIMINARY EXAMINATION OF LUNAR SAMPLES FROM APOLLO 11: Science, vol. 165, no. 3899, pp. 1211-1227, 19 September 1969. Curious about the samples of moon rock and soil that were brought back from the Apollo 11 landing in Mare Tranquillitatis on 20 July 1969? This report written by the Lunar Sample preliminary Examination Team is the first scientific report on the examination of the lunar material brought back in these samples. It presents a physical, chemical, mineralogical, and biological analysis of 22 kilograms (48.4 pounds) of lunar rocks and fines. In addition, the report describes the Lunar Receiving Laboratory and its operations and the methods of handling and protecting the samples from contamination before testing. Geologists will be particularly interested in the very detailed descriptions of the geological setting from which the lunar samples were obtained, the physical properties of the lunar material, the mineralogical and petrological descriptions of the sample materials, and the results of chemical analyses, of gamma-ray spectrometry, and of magnetic measurements. Table 1 in the report lists 23 elements that were detected in a suite of 12 typical lunar samples. Some 18 major findings of the preliminary examination of the lunar samples are given as conclusions, and the last section of the report is given over to a discussion of the findings.

Harbour, Jerry, GEOLOGIC MAPPING OF THE MOON: Geotimes, vol. 14, no. 7, pp. 14-18, September 1969. This article tells how the geologic maps of the moon are prepared at the U. S. Geological Survey's Center of Astrogeology at Flagstaff, Arizona. The delineation of geologic units and structures that are portrayed on the lunar maps begins at the telescope, on telescope photographs, and space-craft-derived photographs. The principles involved in the geology mapping of the moon are the same as those for mapping the earth. The article discusses the application of these principles to the preparation of the lunar geology maps and the sizes and scales of the maps for different purposes. Maps have been or are being prepared on scales as small as 1:5,000,000 and as large as 1:5,000. Many of these maps are scheduled for publication in the near future.

Lowman, Paul D., Jr., LUNAR PANORAMA: A PHOTOGRAPHIC GUIDE TO THE GEOLOGY OF THE MOON: Weltflugbild Verlag Reinhold A. Müller, CH 8706 Feldmeilen, Switzerland, 136 pp., 1969. Price \$10.00. This book contains photographs from Surveyors, Lunar Orbiters, and Apollo 8. The text in English.

VIBRATION EFFECTS OF EARTHQUAKES ON SOILS AND FOUNDATIONS: American Society for Testing and Materials Special Technical Publication 450, 267 pp., 1969. Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103. Price \$18.50 plus shipping charges. This volume contains nine chapters made of papers by 17 authors that were given at a symposium in San Francisco, California, on the same subject June 23-28, 1968.

White, C. G., A ROCK DRILLABILITY INDEX: Colorado School of Mines Quarterly, vol. 64, no. 2, 92 pp., paperback, April 1969. Available from Department of Publications, Colorado School of Mines, Golden, Colorado 80401. Price is \$4.00.

Jaeger, J. C., and Cook, N. G. W., FUNDAMENTALS OF ROCK MECHANICS: Methuen and Company, Limited, 513 pp., 1969. Available in the United States from Barnes and Noble, Inc., 105 Fifth Avenue, New York, New York 10003. Price is \$19.00.

COMING EVENTS

Dec. 10-12 - Annual Midwest Groundwater Conference, Lexington, Kentucky (John Thiaikil, Dept. of Geology, University of Kentucky, Lexington, Kentucky 40506).

Jan. 29-30 - Groundwater short course for explorationists, Socorro, New Mexico (W. K. Summers, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801).

Feb. 15-19 - Society of Mining Engineers of AIME. Annual Meeting, Denver (J. C. Fox, AIME, 345 East 47th Street, New York 10017).

World Trade Center . . .

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The tie-back tendons themselves, consist of up to 24 one-half-inch-diameter, high tensile strength strands, running from 40 to 115 feet in length. A continuous anode runs the entire length of each tie-back.

Welded Top and Bottom

The zinc anode was welded to the tie-back at both the top and bottom for added strength and to ensure good electrical contact in the event the zinc should become completely consumed at any one specific point.

"The use of tie-backs is a new idea here in New York," Mr. Kennedy noted, "we feel that this type of system will provide us with a degree of flexibility during the construction of our foundation which would have been impossible had we chosen, instead, to use interior supports for the perimeter wall. There is no doubt that the corrosion control system employed for the protection of these tie-backs will have a marked effect on the over-all safety and efficiency of the system during the next five years or so that it will be in use."

Chairman . . .

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In order to properly evaluate the data obtained from aerial photos, geophysical explorations, borings, borehole photography, etc., it is essential that we become personally acquainted with the area. As we gain experience, our time becomes more valuable, the hills get higher, the miles seem longer; and as we become acclimated to a comfortable office, the temptation to depend on our experiences, successes, and intuition gets stronger.

Our success in the past thirty years is the result of our continued willingness to tramp over the ground, observing exploration equipment in operation, examining samples, as well as performing many other field chores and combining the knowledge thus obtained with that made available to us from appropriate modern equipment. I am sure that the years ahead will be increasingly gratifying, and our advice more widely sought and accepted if we keep in mind that our product is a personal service and continue to do the detailed geological work that is necessary for making sound decisions.

I will soon join the list of past chairmen, humbly, for those before have given much, and our future officers will build on this and serve well. I give sincere thanks to all for the support that I have received.

W. Harold Stuart



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