CONTRIBUTIONS BY DRILL EQUIPMENT OPERATORS TO EARLY GEOTECHNICAL FIELD INVESTIGATIONS IN EASTERN CANADA

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ABSTRACT

The contributions to geotechnique of organizations and individuals in various fields of expertise, such as developers of drilling and sampling equipment, geologists, and geotechnical engineers, are well covered in the published technical literature. By comparison, there is little written about the work of geotechnical drillers. This paper describes some such contributions by drillers to geotechnique in eastern Canada from a historical perspective.
The paper makes reference to field investigation procedures in "early days" (before the 1930's) and "formative years" (1940's to 1960's) in which there was an increasing level of geotechnical engineering applied to site investigations. Aspects of the training of drillers who pioneered geotechnical site investigations are described with special reference to those with initial experience gained in diamond drilling for the mineral exploration industry. The significant contributions of drillers to the success of major site investigation projects with challenging logistical problems is illustrated by several case histories from the authors' experience.

RESUME

Les contributions aux organismes géotechniques et des individus dans les divers domaines d'expertise, tels que des réalisateurs d'équipement d'échantillonnage de forage et, de géologues, et d'ingénieurs géotechniques, sont bien couverts dans la littérature technique. Par comparaison, là peu est écrit au sujet du travail des foreuses géotechniques. Cet article décrit quelques telles contributions par des foreuses à géotechnique au Canada de l'Est d'une perspective historique.
Le papier fait la référence aux procédures d'investigations de champ en "jours tôt" (avant 1930) et "années formatrices" (1940's a 1960's) dans ce qui il y avait un niveau croissant de la technologie géotechnique appliqué aux investigations d'emplacement. Des aspects de la formation des foreuses qui ont frayé un chemin des investigations géotechniques d'emplacement sont décrits en se référant tout particulièrement à ceux avec une expérience initiale acquise dans le diamant forant pour l'industrie d'exploration minérale. Les contributions significatives des foreuses au succès des projets principaux de recherche d'emplacement avec des problèmes logistiques provocants est illustrées par plusieurs histoires de cas de l'expérience des auteurs.

1. INTRODUCTION

The importance of good information on the subsurface soil and rock conditions at a site to the solution of engineering design and construction undertakings has long been recognized. Much has been written on the contributions of organizations and individuals in various fields of expertise important to securing such information. Examples are: on geotechnical issues (Terzaghi, 1953), (Terzaghi & Peck, 1948); on engineering geology (Legget, 1962); on exploration and sampling operations (Mohr, 1943); and on development of equipment for subsurface exploration purposes (Hvorslev, 1949). Surprisingly (in the Authors' view) there is little by way of specific recognition given in the geotechnical literature to the contributions of teams of individuals who operate subsurface exploration equipment. These teams are usually headed by a Foreman (designated herein variously as Drill Equipment Operator, or Driller) and, depending on the size of the project, may include other personnel such as a driller's assistant (Helper) and one or more labourers. The basic team is supplemented, where required, by others and particularly specialists in logistical support. One reason for the lack of recognition may be that subsurface exploration remains very much an information service providing basic data for end-users such as geologists and engineers. In reality, the contribution by equipment operators has been significant in a number of different ways. The contributions have spanned a period which, in its early stages often required the Drillers to be in charge of both carrying out and recording the results of field investigations, and more recently involves geotechnical engineers or technicians who provide full-time engineering supervision.

This paper makes reference to "early days" before the 1930's but will focus mainly on what are termed herein "formative years" (1940's to 1960's) when geotechnical field exploration activities in Canada were in a strong stage of development. It's main intent is to recognize the contribution of Canadian Drill Equipment Operators during this early period. A number of "old timers" with whom the Authors were privileged to work in Eastern Canada, beginning in the early 1950's, are identified in the paper. However, the Author's would like to dedicate the paper to all Canadian pioneer Drillers. The comments given herein for the "formative years" are based to a large extent on the personal experiences of the Authors who were involved not only as engineers supervising the work of drill teams in the field, but also in managing the field exploration activities of a geotechnical consulting Firm (Geocon Ltd.) which owned and operated a range of drills and other equipment for engineering site investigations, particularly for sites located under water. They are believed to be reasonably representative of the experience of others involved in the Canadian geotechnical profession at the time.

Inasmuch as many pioneer Drillers grew up professionally in the mineral exploration field, it is pertinent to review briefly (in Chapter 4 herein), the equipment on which these individuals gained their early experience prior to converting to geotechnically-related work, and the conditions under which they obtained their initial training. The conditions were, no doubt, similar for Canadian Drillers who trained through other industries such as oil exploration and water well developments.

2. THE EARLY DAYS

As pointed out by Legget (1962) "test boring and sampling (of a sort) were a regular feature of construction work long before soil mechanics had been thought of as a separate discipline". There are interesting published case histories of the use of borings to establish ground conditions at important Canadian projects in the years prior to the 1930's. Examples are included in the following. Some details are provided particularly to illustrate the challenges faced by Drillers:

1. Site Investigations carried out in the 1860's for a railway bridge over the Miramachi River near Newcastle, New Brunswick. Legget and Peckover (1973). The site has a tidal range of 10 ft. (3m), a depth of water ranging between 15 and 33 ft. (4.6 and 10.0m) below high water, and is subject to tidal currents. Initial borings were carried out with "only such boring implements as could be extemporized in the neighbourhood by a country blacksmith". They were supervised by the Driller who reported a bed of silt overlying a hard formation which he assumed to be sandstone bedrock which continued under the river from a rock outcrop on the river bank. Early in the construction phase it became evident that the material thought to be bedrock was in fact dense sand and gravel. This was confirmed by a second set of borings using "more perfect boring implements". This supplementary investigation, as described by Peckover and Legget (1973) also included one of the first recorded examples of carrying out plate load tests on ground at the bottom of cased boreholes.

2. The Sarnia, Ontario to Port Huron, Michigan St. Clair River Railway Tunnel (Engineering News, 1890). Here the water depth is about 40 ft. (12 m) and depth to bedrock (from river level) about 100 ft. (30 m). The overburden was described as “sand, gravel and boulders over soft yet tenacious blue clay”. Eleven borings were put down over water in 1885 from an anchored scow working in an 8 knot current. “A 6 in. wrought iron pipe was driven down into the river bottom by a pile driver, often clear through the sand and gravel to the clay. The pipe was in 12 ft. sections coupled with screw joints. The borings were made inside this pipe as on land.” An additional 110 borings were put down along the tunnel alignment to the top of the clay stratum in 1888.

3. The Midland Railway Co. Shubenacadie River Bridge in Nova Scotia built in the late 1890's (Taylor, 1905) in an arm of the Bay of Fundy. Site conditions included an extreme tidal range of about 33 ft. (10 m) and a Bay of Fundy “Bore” of up to 2 ft. (0.6 m). Borings were made with a rig owned and operated by Messrs. McDonald & Co. of Halifax, with the objective of determining “the strata and locate the bedrock” and “taken in the manner described in the specification”. The rig consisted of “a sort of miniature pile driving arrangement with a 150 lb. dolley or hammer on the drill. “The soil strata at the site were inferred to consist variously of shifting sand, gravel, clay, and loose stones. The reference notes that “it was found impossible to get a pipe down about the drill through the compact gravel, etc” and that “the 1 1/4 in. drill was turned as it went down, but drove very slowly. In the deepest place on site it took two hours to drive the drill 20 ft., with four men on the lifting rope.” The maximum depth to bedrock below extreme high water level, was about 60 ft. (18 m). In four borings which penetrated overburden, bedrock as encountered during construction was about 2 to 13 ft. (0.7 to 4 m) below the “supposed” level inferred from the borings. It is of interest that the paper states that “one of the many lessons that this work taught was the great importance of accurately designating the strata through which it becomes necessary to go to reach the bedrock, and to accurately determine the elevation of the bedrock.” Apparently the contractor for the caissons for the bridge piers ran into financial difficulties just before completing the work, otherwise “the probabilities are that expensive litigation would have been the result of inaccurate borings.”

4. A million bushel concrete grain elevator at Transcona, Manitoba which was carried on a raft experienced a bearing capacity failure during first filling in 1913. Borings established that it was founded on deep lacustrine clay. The structure was successfully underpinned and righted in what was claimed to be one of the most difficult underpinning projects carried out anywhere up to that time. (Foundation Group of Companies, 1975); and (Baracos, 1957).

5. Numerous hydro-electric dams and powerhouses were constructed in Canada in the early 1900’s with the main structures founded on bedrock. Borings were generally carried out to establish overburden and bedrock conditions. A case in point is a concrete dam at Fraserdale, Ontario where exploratory core holes were drilled in the foundation bedrock and in-situ pump-in type tests carried out to assess the permeability of a prominent fault zone (Taylor, 1934).

6. Borings were put down in 1942 through 100 to 150 ft. (30 to 45 m) of clay till at a site for an industrial plant site in Sarnia, Ontario. The Test Boring Branch of Public Works Canada was engaged under a special arrangement probably because of lack of private Firms who specialized in such work (Legget, 1948).

7. In 1949, borings were put down for the Canso Straits Causeway, N.S. at a site with water depths greater than 100 ft. (30m), tides of 10 ft (3m) and currents of 6 knots. The drill platform was carried on a guyed tubular steel tower handled by a crane-equipped derrick boat. A similar set-up was later used in 1958 at a site in the Azores Is, Portugal, exposed to the ocean. (Matich and German, 1979).

The contributions of Drillers to geotechnique in the early days were significant when it is considered that they not only had to cope with the logistical and operational problems involved, but often also take charge of details of the field program and record keeping as well, with only periodic supervision from engineers or geologists. This is in contrast to the situation today where a Driller can at least work to detailed specifications in cases where he does not have full-time technical supervision on site.

3. THE FORMATIVE YEARS

Terzaghi (1953) stated that, in contrast to the first 20 years of the preceding 50 year period when practically no progress was made, the last 30 years witnessed the transition from primitive, almost rigidly standardized procedures to a great variety of highly specialized techniques. This development, (which took place during a “formative” period as designated herein), is also mentioned by Legget (1962) who stated that the refinements that modern soil studies have introduced into subsurface exploration have transformed what was at best a rough and ready sort of procedure into a highly skilled, reliable, and thoroughly scientific operation. During the 30 years of development mentioned by Terzaghi, there were many large engineering organizations in North America, such as highway and public works administrations, e.g. Public Works Canada, who maintained a test-boring division for carrying out their regular exploratory work. In cases where consulting engineers or engineering offices were not able to maintain boring crews and equipment, it was generally possible to engage an outside test-boring contractor.

In 1953, at the time of Terzaghi's classic address, Montreal-based Foundation Company of Canada Limited (Foundation), (then a major construction organization), maintained drilling equipment and crews on a full-time basis specifically for site exploration purposes, as well as a team of geotechnical engineers and an experienced multi-disciplinary group of designers and construction engineers. This organization formed Geocon Ltd. as a Division specializing in geotechnical engineering, in 1954. Foundation, through a marine salvage subsidiary, also owned a fleet of tugs and other marine plant. Foundation’s diversified resources thus greatly facilitated Geocon's capability to carry out investigations over water. The Montreal consulting engineering Firm of Lalonde and Valois, similarly maintained drill rigs and crews and geotechnical engineers in 1953, and formed at about that time a subsidiary National Borings and Soundings, Inc. (NBS) under the leadership of Mr. Marcel Dufour, Ing. There were also a number of test-boring contractors who were beginning to specialize in work for geotechnical purposes, such as F.E. Johnston Drilling Company in Ottawa, and Dominion Soil Investigations Inc. in Toronto. In addition, there were organizations and individuals with a long history of exploratory drilling of rock for mining and major civil engineering projects such as dams, bridges, tunnels, etc. This situation still exists, of course, as evident from the Professional Directory or the Northern Miner publication. Firms such as Boyles Bros. of North Bay, Ontario and Canadian Longyear of Toronto were already established in the manufacture of drilling equipment.

Geocon and NBS based their site exploration equipment initially on diamond drilling rigs and employed mostly Drillers with many years of prior experience in the mining industry. They preferred full-time supervision of major drilling and sampling operations by civil engineers who had specialized in soil mechanics at university level. This approach was also adopted by various other organizations in the geotechnical engineering field in Canada at the time. It was thus that early field investigations brought together as a team the hitherto highly improbable combination of ambitious young engineers, fresh from the experience of studies under the great men of soil mechanics in some of the world's greatest institutions of learning, but with little practical field experience, and Drillers from the Canadian mineral and oil exploration industries. The latter were, by virtue of the bush environment in which they often worked, and the very nature of their work, generally a group of older, tough, experience-hardened, very practical men whose knowledge and skill was, as discussed in more detail later, obtained completely through the process of on-the-job training. One of the few things that the two categories of individuals had in common professionally was that they had studied under men who were leaders in their profession and who insisted on a high standard from their students. During these formative years when geological and geotechnical engineering expertise was being increasingly applied to development of site exploration equipment and techniques, Drillers played a significant role by virtue of their experience with working under diverse field conditions and familiarity with the one of the main type of drill units selected for geotechnical work, then in use, namely the diamond drill.

4. ACQUISITION OF SKILLS AND EXPERIENCE

A good account of conditions under which pioneer Drillers gained their experience is given by Fivehouse (1976), Project sites were often located in remote parts of the country. Challenging logistical problems were generally associated not only with access but also with the drilling operations, particularly where the drill rigs were originally skid-mounted and powered by steam engines. In the earliest undertakings, the Drill crew might have to rely for transportation on dog teams, pack trains of horses, or whatever other local resources they could find. With the passage of time, transportation facilities gradually improved with the introduction of aircraft equipped with skiis and floats, and helicopters, and with the ability to mount drills on Bombardier-type tracked vehicles. Figure 1 shows a typical straight-forward operation were a Driller is preparing to drill from a raft on a remote Northern Lake.

Early diamond drillers also had to endure long absences from families and the need to operate at times for extended periods in the severe winter conditions of the Canadian North. Fivehouse gives an apt description of some of the old time drillers, as follows: “The diamond drilling industry concerns itself with a relatively limited but very technical set

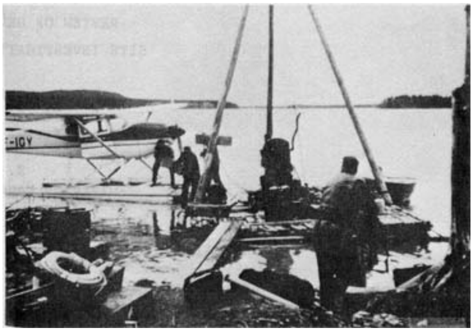

Figure 1. Edgar Belley setting-up to drill.

of reference points: linear feet drilled, dollar cost per foot of drilling, percentage of usable core retrieved, percentage deviation from true of the drill hole and so on. It is detail work, but detail work carried out in locations and under physical conditions which constitute some of the most hostile and strenuous working environments to be found in any occupation. The peculiar requirements of this work - physical and mental toughness, technical expertise and special problem-solving abilities - set diamond drillers apart as a very curious breed of craftsmen. The pressures of work often inspire drillers to develop as very individual - and colourful – characters"

As described by Fivehouse (1976) and Cumming (1956) the first modern diamond drill was developed by Swiss Engineer Jean Rudolphe Leschot in 1862 for drilling blast holes on the France-to-Italy Mt. Cenis Tunnel. Diamond drills were at work on mining projects in Eastern Canada (Springhill, Nova Scotia and Port Arthur, Ontario) in the early 1870's, and were being marketed in Canada in 1913 by Mussens Ltd. of Montreal. Diamond drills were later manufactured in Canada by the internationally known Boyles Bros. and Longyear Organizations. Of the many models they produced, the Boyles Bros BBS-1 and Canadian Longyear Junior A or Model 38 were in common use in initial geotechnical applications in Eastern Canada.

For pioneer Drillers the main objective was to drill bedrock and recover good core. Sampling of the overburden was generally not called for. The skills required for recovering good core of bedrock by diamond drilling could only be acquired by diligent on-the-job training over a number of years. Conversion of diamond drillers to geotechnical site investigations required that they acquire skills in sampling and testing of the overburden for engineering purposes, as this now was the main focus of their operations albeit with much less colour and romantic appeal than mineral exploration. Drillers had also to learn how to carry out a variety of tests in boreholes, (such as penetration tests, vane shear strengths, and permeability tests) and install monitoring instrumentation such as piezometers, slope indicators, and thermistors. They also had to acquire skills in operating with drilling fluids other than water (such as chilled brine for coring permafrost), and in conducting drilling with equipment different in many respects from the diamond drill, such as the Swedish Foil Sampler and hollow stem auger drills. The Swedish Foil Sampler was developed to

Figure 2. Drill crew operating Swedish Foil Sampler

take long undisturbed samples of Scandinavian sensitive clays (Kjellman et al., 1950). A head containing rolls of steel foil is jacked into the ground. The foil unwinds as the casing advances, and prevents friction between the soil sample and the casing. The equipment, which was introduced into Canada by Geocon in the 1950's, is shown in operation at a Canadian site in Figure 2. (Geocon Photo). The head and casing are shown schematically in Figure 3 (Foundation Companies Canada, 1975). Significantly, the previous experience and resourcefulness acquired by on-the-job training enabled the Drillers to become proficient in these new tasks without special dedicated training sessions.

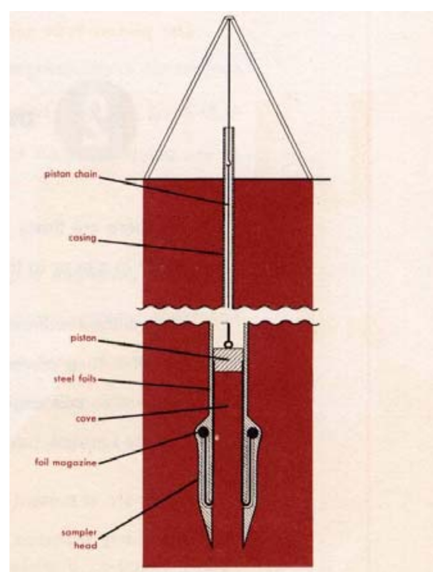

Figure 3. Schematic of Swedish Foil Sampler

An important aspect of the contributions of Drillers, in the Authors' experience, was in their assistance to engineers in the practical aspects of site work. The fundamentals of site investigations were covered in university courses, and Professors (Terzaghi, in particular), stressed the importance of acquiring practical experience in the field after graduation.

Illustrations of drill rigs and basic soil sampling and rock coring tools are given in textbooks such as Terzaghi & Peck (1948), and Legget (1939, 1962), along with some general comments on the observations which should be made by the Driller during advancement of boreholes. The involvement of Drillers in tests (e.g. the Standard Preparation Test) was later included in publications such as Ireland et Al (1970), and standards, ASTM (1984) and CSA (1960). Fledgling Engineers learned to take advantage of Drillers' practical experience, their good sense for the geology of a site area, and also how to operate safely and effectively in remote areas under difficult climatic and marine conditions. Strong and effective teamwork between engineer and drill crew was important and usually developed in the process. These educational aspects no doubt continue to apply to the present day.

An interesting comment on the matter of training which illustrates the versatility of the older Drillers relates to their assignment in training other geotechnical drillers in situations involving transfer of technology and "know-how". The Authors have observed that, despite having obtained their experience on-the-job, Canadian Drillers have demonstrated the ability to teach others largely by instruction rather than by example alone.

5. SITE INVESTIGATION PROCEDURES

In the case or organizations that employed Drillers and Soils Engineers, and also maintained an inventory of drilling, sampling and testing equipment, the practice which evolved in respect to the conduct of geotechnical field exploration projects, particularly the involvement of Drillers, included the following main components (in summary) which are believed to be representative of practice generally on major projects in Canada at the time.

It should be noted that, in the formative years, investigation methods relied primarily on extracting soil samples and rock cores for examination and laboratory testing, although indirect methods based on geophysics and testing by probes (such as static cone penetration tests) were beginning to be used. As indicated below, the successful planning and execution of major site investigation projects often involved the combined efforts of a number of specialists (such as experts in geology, soil mechanics, structural and foundation design, hydraulics, marine navigation and construction etc.) as well as the Drill Team. However in the final analysis, it was the Driller who was responsible for extracting soil samples and cores of bedrock from the earth in intact and usable form.

1. A site reconnaissance.
2. An initial program of field investigation consistent with the proposed development.
3. Assessment of logistical and operational needs in respect to equipment and facilities. Equipment requirements would be itemized in a "Bill of Materials".
4. Where necessary, special equipment for drill support would be designed and pre-fabricated and floating plant (barges, ships, etc.) would be suitably outfitted.
5. Personnel assigned might include a variety of skills, particularly for logistical support purposes. However, the Drill Team and Soils Engineer were the key.
6. Reports would be submitted from the field to Head Office daily using available communication facilities, (sometimes by telegram).

The Drillers' contribution in each of these areas was significant but nowhere more so than in completing the "Bill of Materials". To an important extent, both the Engineers and Drillers had to anticipate the subsurface conditions at the site in assessing needs of basic equipment and spares. Input from an experienced Driller in this respect could make a great difference to effectiveness and efficiency. Experienced drill operators developed a good sense for the geology of a site area. Their observations during advancement of boreholes were important when estimating strata boundaries, etc. based on inspection of recovered soil samples and rock cores. Soils engineers supervising field operations were therefore wise to coordinate their initial interpretation of progress findings with the drill crews.

6. SOME SIGNIFICANT SITE INVESTIGATION ACHIEVEMENTS

As alluded to earlier, pioneer Drillers who converted to geotechnical work had to master types of drilling equipment which were new to them, as well as sampling tools and in-situ (down-hole) testing and monitoring techniques. They also had to become proficient in sampling and coring a wide range of natural overburden types and non-textbook "soils". They achieved good proficiency in these tasks, through essentially on-the-job training. By contrast, modern drillers are likely to have had the opportunity to attend a drilling technology course at a community college involving classroom work and training in well-equipped maintenance shops.

During the "formative years" Drillers were involved in many projects which made demands on their skills in a manner not within their earlier experience base. The projects were diverse and included, in addition to investigation of numerous more conventional sites for buildings, industrial developments, bridges, tunnels, wharves, etc. such undertakings as coring of permafrost and the concrete of dams and powerhouses; drilling into tailings areas and various other waste disposal repositories; and investigations in sites abroad in residual soil areas. Nowhere were the challenges to Drillers greater, however, than in the planning and execution of major drilling programs in sites located over water. Drillers with whom the Authors were associated participated in a number of such projects in the Beaufort Sea; the St. Lawrence River; the Great Lakes; in Canadian East Coast waters (in the Bay of Fundy, Lurcher Shoal, and The Grand Banks) and abroad in the Azores Is., Portugal. In order to illustrate the conditions which Drillers successfully coped with on these projects, three have been selected for discussion below, representing investigations for a tidal power dam; an offshore Lighthouse, and a marine salvage operation, respectively. On each of these projects, there was a diversity of professions involved in planning and building the drill support platforms involved, and in operation of the logistical support. These items represented a substantial cost. However, the success of each project, in terms of the technical objectives, time schedule, and overall costs of the field work depended heavily on the skill and aggressiveness of the Driller, or Drillers, involved. Some details on the proposed developments at the Dam and Lighthouse sites, and the salvage operation, as well as the site conditions and special drill platforms and marine plant required are given by Matich and German, (1979) and Matich et. Al (1998). However, no details of the Drillers' contributions have been provided previously.

6.1 Proposed Tidal Power Dam

This site spans Cumberland Basin and Shepody Bay in the Bay of Fundy, with overwater lengths of Dam of 13000 ft. (3900m) and 15000 ft. (4500m), respectively. Water depths at borehole locations varied from 60ft. (18m) to 100ft. (30m) at low tide. The tidal range at the time (December, 1963) was about 28ft. (8.5m) with reversing tidal currents in excess of 6 knots. After a study of possible alternatives, it was decided to work from a large derrick barge equipped with an on-board crane, powerful winches and anchoring capabilities, and attended by an ocean-going tug. Drillers played an important part in determining the details of the mounting of the drill. It was cantilevered over the side of the barge and, in order to reduce current forces on the unsupported drill pipe, a guide casing was installed which was fixed at barge deck level and also attached to the barge by stay cables. The conductor pipe was therefore partly shielded inside the guide casing. Drilling and sampling presented formidable challenges. For example, the average rate of change of tidal elevation of about 5ft. (1.5m) per hour, was equivalent to a favourable drilling rate for wash boring techniques and faster than the drilling bit could cut into the bedrock and normally recover good quality rock cores. Successful core drilling of the bedrock could therefore only be carried out at slack water and in the initial stages of the rising tide. Conventional soil sampling was carried out through a maximum of 35 ft. (10m) of glacial till with core drilling the same distance into sandstone and shale bedrock. Even with the use of a guide casing, the powerful currents were found to hinder operations due to bending of the conductor pipe and strong vibrations in the latter resulting in loss of pipe on several occasions due to breakage by fatigue. This problem was solved later on another project, as described in Section 6.3 herein. The Drillers solved it by observing how long it took before failure of the conductor pipe occurred due to fatigue, and strove to complete a given borehole before this happened. The work was also hampered by bad weather which permitted work only in short spells.

The success of the project was due to the efforts of many individuals including marine experts, designers, riggers, tug and derrick barge operators, surveyors, geotechnical engineers as well as the Drillers involved. Special credit was however accorded by all to Johnny Johnson, a top-notch Driller from Geocon. He personally drilled as much as 10ft. (3m) of bedrock in the remarkably short time of about 15 minutes and recovered good core! A view of drilling operations in progress is given on Figure 4. (Geocon Photo). Public Works Canada was the Client.

Figure 4. Drilling operations in progress in Minas Basin

6.2 Proposed Lurcher Shoal Lighthouse

In 1966, the Department of Transport Canada commissioned an investigation of foundation conditions at a rock outcrop known as Lurcher Shoal located in the Atlantic Ocean about 16 miles (26kms) west of Yarmouth, N.S. Water depths at the site varied from about 10ft. (3m) to 33ft. (10m) at high tide. Except under the most favourable weather conditions, waves broke menacingly over the Shoal and safe access and operation from floating plant on it was virtually impossible. A team of engineers and drillers therefore designed a self-supporting and levelling drill platform carried on tripod legs of 16 inch (40cm) pipe each filled with 3.5 tons (3.6 tonnes) of steel punchings. The platform was handled by a crane-equipped derrick boat attended by an ocean-going tug. Access onto the Shoal was made during a brief period of favourable weather and marine conditions in 1967. This in itself was a major accomplishment on the part of the marine crews as described by Matich and German (1979).

Figure 5. Driller at work in fair seas, Lurcher Shoal, N.S.

However, credit for the success of the operation rested with the Drillers who completed four coreholes into bedrock in record time. The tripod-mounted drill rig is shown in operation in Figure 5.

6.3 Burial of Wreck MV Tritonica

In 1963, the 19,500 t ore carrier M.V. Tritonica collided with another vessel and sank in the St. Lawrence River about 2.5

miles (4kms) offshore from La Petite Riviere, Quebec. The wreck constituted a navigation hazard and had to be removed or otherwise disposed of to provide 9 fathoms of clearance below low water. The marine conditions at the site involved a water depth of 75ft. (23m) at low tide, a tidal range of up to 20ft. (6m) and tidal currents of up to 10ft./sec (3m/sec/). Waves of up to 10ft. (3m) were common. In order to carry out geotechnical investigations of the sea bottom in these challenging marine conditions, a stationary cable rig type of drill platform was developed by Hydraulics Expert Dr. H.R. Kivisild together with Geocon's soils engineers and drillers. This was an improvement over the drill set-up used on the Bay of Fundy, (as discussed earlier in Sub-section 6.1), in that the drill platform remained stationary relative to the sea floor during drilling, and tensioned cables supported the drill casing against lateral forces and vibratory effects from currents, throughout its whole length. The system, which was suspended from the shear legs of a large derrick boat, was a forerunner to later, more sophisticated motion-compensated drill platforms. Matich and German (1979). A feature which made drilling from the platform very unusual in the experience of both the Engineers and Drillers involved, was that the drill platform hung from a single cable. It took exceptional skills, and much nerve on the part of the Drillers, to work in this position. They were nevertheless able to successfully penetrate the necessary approximately 100ft. (30m) below river bottom into a deposit of sensitive clay, take thin-walled tube samples, and carry out vane shear tests in-situ in eight boreholes. The results, as used in successful lowering of the wreck to below navigation depth by controlled landslides, are described by Matich et Al (1998). In the process, Drillers therefore were party to the introduction of working from motion-compensation platforms in Eastern Canada.

A view of the drill platform and the cable supporting it and a counterweight from a pulley on the shear leg of the barge, is shown in Figure 6.

7. SUMMARY

Exploration for mining and civil engineering purposes using diamond drills began in Eastern Canada in the latter part of the nineteenth century. Drillers on such projects received their training and experience in the only practical way, namely over years on-the-job in the field. On early projects, Drillers were often tasked with record keeping as well as execution. By virtue of this background Drillers were able to contribute significantly to the early years of geotechnical site investigations which were based on the use of suitability modified diamond drills. As equipment for soil sampling and in-situ testing was developed, and new types of drills were introduced, Drillers contributed further by becoming proficient in their use. Drillers also played an important role in assisting fledgling Soils Engineers by sharing their experiences in assessing the site geology and in the practical aspects of field operations. Drillers have also played, (and continue to play), a key role in the planning and execution of major geotechnical site investigations often under very challenging conditions.

Figure. 6 Drillers working from the Stationary Cable Rig

8. ACKNOWLEDGEMENTS

As indicated earlier, the Authors wish to dedicate this paper to all Canadian Drill Equipment Operators as an acknowledgement of the latter's contribution to geotechnique in Canada particularly in the "early days" before equipment and engineering resources for geotechnical field exploration became as well-developed as they are today. The Authors have been privileged to work closely with a few Drill Operator "old timers" during the formative years of Canadian field exploration developments and acknowledge gratefully the way that men such as the following cooperated and shared their skills and experience with us: John "Johnny" Johnson; Roy F. Lipsett; Edgar Belley; Bernard "Barney" Brazeau; Henry Brazeau; Armand Ducharme; Roland DeSorcy; Roger Miller; and Pierre Pepin.

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