Association of Professional Engineers and Geoscientists of Alberta and the *Consulting Engineers of Alberta*. The CEA's "Harold L. Morrison Rising Young Professional Award" recognizes the achievements of young professionals who demonstrate excellence in their field of expertise.

Ian Morrison, who provided much of the above information on his father and grandfather, received his civil engineering degree from U of A in 1979. After graduation, he worked for Montreal Engineering in the construction and quality assurance for the pile foundations of the Keephills coal-fired power plant in Alberta.

Ian subsequently pursued graduate studies, also at U of A, in a co-op program that involved a year working with Thurber Engineering in Calgary. He obtained his MEng in Geotechnical Engineering in 1984 followed by an MBA in 1985. Ian then worked with Trans Mountain Pipeline and TransCanada Pipeline (now TC Energy), both in Canada and internationally, including work on numerous large landslides and specification development for rock blasting in the vicinity of operating facilities.

Ian's career has also included working with the World Bank in Washington, DC and abroad, and as Manager for TransCanada International in Thailand. Since 2001, Ian has been with Stantec in Edmonton where he is currently a Senior Principal and Practice Leader for financial and feasibility analysis. He credits his geotechnical background and experience, where one encounters significant uncertainty, as helping him tackle problems in a variety of sectors.

Ian and Harold Morrison; circa 2010

GEOSCIENCE EDUCATION FOR GEOTECHNICAL ENGINEERS

It is Richard Jackson's opinion that there should be more geoscience in geotechnical engineering programs. In the following, he briefly describes how geoscience has been, and will continue to be, important to Canadian geotechnique, and suggests what an introductory geoscience course in geotechnical engineering should include.

If readers have comments on this article, send to Canadian Geotechnique/Géotechnique canadienne *at lisa@karma-link.ca.*

Richard Jackson

BACKGROUND

In 1842, the Provincial Geologist to the United Province of Upper Canada, **William Logan**, sketched and described in his field notebook a landslide in southeastern Ontario, of the kind now known as a rotational regressive earthflow. This was perhaps the first record by a Canadian geologist of what we know as engineering geology.

By 1900, the *Geological Survey of Canada* had embarked on the study of the urban geology of the principal cities of eastern Canada, then its attention was turned to the bedrock for the foundation of the ill-fated Québec bridge, near Quebec City. (It collapsed twice during construction; in 1907 and 1916.) During World War I, the focus switched to that of aggregates for the expanding highway network between Ottawa, Montreal, and Toronto. The first hydrogeological study was based on wells drilled in Montreal. Post WWI, further hydrogeological studies were undertaken on the drought-stricken Prairies and in the cities of Regina, Moose Jaw, and Ottawa.

All these studies occurred before the vast expansion of Canadian infrastructure during and after World War II, and provide an indication of how important the practical applications of geoscience were to Canada's early development.

During the 1960s, one geotechnical engineer, **Peter Parsons**, developed the methods of high-resolution soil mapping of 90Sr (strontium 90) plumes in an outwash sand aquifer at the Chalk River Nuclear Laboratories in Ontario. It's been argued that such studies at nuclear facilities laid the foundations of the subdiscipline of contaminant hydrogeology. On the Prairies, Parsons' work was complemented by the much better-known development of the theory of groundwater flow systems by **József Tóth**, **Peter Meyboom**, and **Allan Freeze**. Complementing this interest in groundwater, the focus of engineering geology in the 1970s moved on to how geological systems posed geotechnical problems including the sensitive clays of Québec and the Ottawa Valley, prospective dam sites, urban geology, dewatering excavations for canals, and the effect of glaciotectonics on Quaternary sediments.

Landslides continued, as in Logan's time, a geotechnical preoccupation; whether in open-pit mines or along transportation routes. This was particularly so following the Vaiont Dam disaster of 1963, in Italy. Vaiont produced innovative investigations by Canadian geotechnical engineers, such as Frank Patton, and led to innovations such as multi-level piezometers, since used across Canada.

This rich history of weaving geoscience with geotechnical engineering has been critical to the development of Canadian geotechnique. And it will continue with more pronounced droughts, floods, landslides and coastal storm surges, the result of climate change. Furthermore, we must expect that a major earthquake will again shake Cascadia, as well as lesser events along the St. Lawrence Valley. Finally, weathering, aqueous geochemistry, sensitive clays and fluvial erosional processes will all remain central to geotechnical and geoenvironmental engineers practicing in Canada.

PUTTING "GEO" INTO GEOTECHNICAL

Thus, geoscience is important to the training of civil engineers, particularly those practicing geotechnical and geoenvironmental engineering. However, the Canadian Engineering

Accreditation Board, the body that accredits undergraduate engineering programs, requires only that "...it is vital that all accredited engineering programs have a clearly identifiable natural science component." (CAEB, 2019)

In most cases, civil engineers are introduced to geoscience with a course on physical or environmental geology taken in their first or second year. This practice raises the issue of whether a civil engineer, who is licensed to protect public safety and with a responsibility to safeguard infrastructure, is well served by only one such introductory course. Several eminent twentieth century geotechnical engineers, including **Karl Terzaghi** and **Alec Skempton**, had strong interests in the geological aspects of soil mechanics and promoted geoscience in its application to geotechnique. I believe they were correct then, and their recommendations remain valid; however, they have been frequently ignored.

Consider **Karl Terzaghi**, a not insignificant figure in geotechnical engineering, who recommended in his presidential address of 1957 to the 4th International Conference on Soil Mechanics and Foundation Engineering, "a two-semester course combined with field trips" taught by "a geologist who appreciates the requirements of engineers and an engineer who has learned from personal experience that geology is indispensable in the practice of his profession." (Terzaghi 1957, cited by Proctor, 1981)

Does such a course exist anywhere in Canadian universities? I doubt it because of the conflicting demands of accreditation, i.e., degree course requirements for a supposedly four-year BASc/BEng degree, and insurance costs for field trips have caused the disappearance of geoscience from the civil engineering degree programme. The combined effects of these causes have been overwhelmingly negative.

Now consider **John Burland**, whose lectures in several Canadian cities in 2019 were much celebrated. Burland observed how geotechnical failures associated with inadequate site investigations were often caused by hydrogeological phenomena: "nine failures out of ten result from a lack of knowledge about the ground profile - often the groundwater conditions." (Burland, 2007) This observation suggests that the practice of site investigation might be a suitable topic around which to build an introductory geoscience course for geotechnical engineers at the master's level. In this framework, engineering geology, geotechnical engineering and hydrogeology can be integrated in a complementary approach for those about to enter geotechnical practice. At this stage of their education, young engineers are likely receptive to such coursework that is so clearly applicable to their future. This is not necessarily the case during their undergraduate years when career paths are uncertain and site unpredictability is probably not appreciated.

What might such a course include? At the very least, I believe it should address:

- plate tectonics and occurrence of volcanism and seismicity (natural hazards);
- ore deposits: origin and development of ore bodies;
- structural geology: measurement of attitude of features; fractures/discontinuities; attitude of fractures and rockfall, origin of stress regimes, nature of rock fracture;
- geomorphology: weathering and its effect on rock mass stability, identification of evidence of landslides and active faulting, paleoflood hydrology, muskeg and permafrost;
- terrain analysis tools: LiDAR, aerial photographic interpretation, satellite imagery;
- glacial and fluvial sediments, saprolite, tropical soils, sediment erosion and transport processes, sedimentation in reservoirs;
- hydrogeology: variations in hydraulic conductivity, flow systems, contamination;
- effects of mining and groundwater extraction on land subsidence;
- earthquake science: seismic waves, identification of active faults, paleoseismology, nature of liquefaction, seismic hazard analysis; and
- coastal hazards: rise in mean sea level, storm surges and tsunamis, erosion of beaches, bluffs and cliffs.

Richard Goodman, a Professor Emeritus of Geological Engineering in the Department of Civil and Environmental Engineering at University of California, Berkeley, and Terzaghi's biographer, wrote of teaching geoscience to civil engineers: "No doubt, mastering advanced engineering mathematics or thermodynamics is 'harder' for some students than understanding the principles of engineering geology. But in the practice of engineering, geology may prove to be the harder subject. The penalties for geologic mistakes can be severe, whereas the confidence that comes from having made the right choice cannot be obtained from a formula or theory. In my experience, most engineering students are more at home with formulas and analysis than with colors and grades of truth." (Goodman, 1993)

The integrated nature of engineering geology, geotechnical engineering and hydrogeology is not clearly presented in academia, perhaps because many engineering geologists, geotechnical engineers and hydrogeologists tend to live in separate technical communities without even a consensus on shared terminology, for example, the use of the term "permeability". If the protection of human life and infrastructure were irrelevant to what we as engineers do over the course of our careers, then this subject matter would not matter. But what Terzaghi, Burland, and Goodman have written in the twentieth century does matter and we are bound by oath to protect life and infrastructure, so we need to think through how we are to discharge these responsibilities in this century.

References

Burland, J. 2007. Terzaghi: back to the future. *Bulletin of Engineering Geology and the Environment* 66, pp. 29-33.

Canadian Engineering Accreditation Board, 2019, 2016 *Accreditation Criteria and Procedures*, Revision of 2019, Appendix 2: Interpretive statement on natural sciences, pp. 51.

Goodman, R.E. 1993. *Engineering Geology: Rock in Engineering Construction.* John Wiley and Sons, New York. 432 p,

Proctor, R.J. 1981. Let's teach geology to the Civil Engineering student. *Issues in Engineering—Journal of*

Professional Activities, American Society of Civil Engineers 107, EI1: pp. 61-63.

Richard (Dick) Jackson is an Adjunct Professor at the University of Waterloo and a Fellow with Geofirma Engineering of Ottawa. He received the 2008 CGS Geoenvironmental Award and the 2013 Farvolden Award. He is a P.Eng. in BC and Ontario. Cambridge University Press published his Earth Science for Civil and Environmental Engineers in 2019.

Richard Jackson

CANADIAN GEOTECHNICAL ACHIEVEMENTS / RÉALISATIONS GÉOTECHNIQUE CANADIENNES MARQUANTES

In 2017, the Canadian Geotechnical Society asked members to submit suggestions of Canadian Geotechnical Achievements. These were profiled at GeoOttawa 2017. Over a number of issues, Canadian Geotechnique/Géotechnique canadienne *will present the achievements that were selected to be profiled. The two achievements this issue relate to the Confederation Bridge, between New Brunswick and Prince Edward Island, and to the Toronto subway system.*

En 2017, La Société canadienne de géotechnique a demandé ses membres de soumettre des suggestions de réalisations géotechniques canadiennes marquantes. Ces réalisations one été présentées à la conférence GeoOttawa 2017. Dans ce numéro et quelques autres Géotechnique canadienne/Canadian Geotechnique *publiera certaines de ces réalisations qui on été sélectionnées pout être présentées.*

CONFEDERATION BRIDGE GEOTECHNICAL INVESTIGATIONS AND FOUNDATION DESIGN

Construction of large diameter battered drilled concrete shafts for approach spans (1994-1995) / Construction des piles sur pieux en béton battus et forés à large diamètre pour les travées d'approche (1994-1995)

Geographical Location

Confederation Bridge spans 12.9 km across the Northumberland Strait and provides a permanent link between Cape Tormentine, New Brunswick and Borden, Prince Edward Island.