Geoscience Canada

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Volume 5, numéro 3, september 1978

URI : https://id.erudit.org/iderudit/geocan5_3art02

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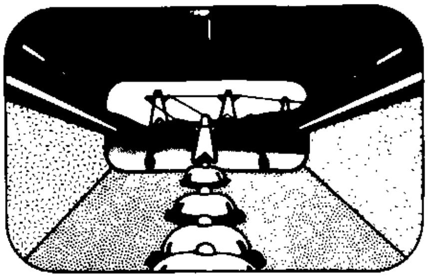
Éditeur(s)

The Geological Association of Canada

ISSN

0315-0941 (imprimé)
1911-4850 (numérique)

Découvrir la revue



Energy, Geology and the Underground

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The energy situation in North America is not a "crisis" that will peak and then happily disappear but rather a continuing condition, already critical, that is getting progressively more serious. Geoscientists, as well-informed citizens, are generally appreciative of this disturbing continental problem. They know well the vital importance of Geology in the exploitation of fossil fuels. They know, equally well, that these are exhaustible and so provide no answer to the long-term demand. Engineering geology is involved in the building of all power plants, and in the experiments - already under way - to trap some of the heat of the earth for human use.

There is another application of Geology which can make a useful contribution to the energy problem, one still generally unrecognised. This is the use of underground space for appropriate purposes, where local geological conditions are suitable, as a significant conserver of energy. There are more immediate means of energy conservation, some of which are now receiving public attention, but taking the long-term view (as must be done in the development of energy policies), proper use of the underground presents appreciable potential for worthwhile reductions in the use of energy. When it is recalled that between one quarter and one third of *all* the energy used in North America is devoted to the heating, cooling and operation of buildings, then the importance of this potential saving can be the better appreciated.

To those unfamiliar with what has already been done in the appropriate use of the underground, as for example in Kansas City, the idea of "going underground" may appear strange, if not indeed ludicrous. "Do you want us to live like troglodites?" is a common initial reaction. Use of the underground for *appropriate purposes* must therefore be stressed at the outset, such as for the storage of gases and liquids and especially solid material for dead storage (archival material, for example), and for light manufacturing and other industrial operations normally carried out by artificial light in single-storey buildings. Even with this qualification the idea still seems visionary to many - including some of the writer's friends, although with their usual courtesy they have never actually told him that he was crazy. But to set his own mind at rest, and to see if others thought as he did, he decided to attend the first international conference on underground storage. Dubbed *Rockstore '77*, this meeting was held in Stockholm, Sweden, in September 1977.

Expecting to be one of a small group of enthusiasts, the writer found himself as one of a company of over 1,100, gathered together from every continent, almost 50 countries being represented. Underground storage projects now in existence in 14 countries for two dozen varied uses such as storage of fuel oil and molasses were described in the 112 papers, only a selection of which could be presented at the meeting, but all of which are published in the printed Proceedings (Bergman, 1978). The importance of Geology was implicit or explicit in almost every paper, to such an extent that there was no need for any separate session devoted to geological considerations.

Sweden is in the forefront of using the underground. Excellent field trips enabled participants in *Rockstore '77* to see some significant Swedish achievements in this field. Longer trips including underground projects throughout Scandinavia. One of the installations visited by the writer was the main establishment of the Swedish State Liquor Commission. Here is stored 50 per cent of all the wines and spirits consumed throughout the entire country - an impressive sight - all in underground caverns without the use of any energy for heating or cooling, the surrounding ground temperature being just that required for this sensitive storage.

Stockholm now has four of its five sewage treatement plants underground, the earlier plants for defence reasons, the later plants for strictly economic considerations. The civic archives and storage of national archives are underground. Defence installations underground are known to be extensive, typical being a hangar for small aircraft and a dock at sea level into which two destroyers can be sailed. Of special significance is the fact that all oil installations (Fig. 1) in Sweden are now being placed underground. Such is the efficiency of Swedish rock excavation methods, in the competent Precambrian rocks of the country, that underground oil installations can now be secured for two thirds of the cost of corresponding surface installations. Groundwater is no real problem since oil is lighter than water, a controlled water cushion being maintained by pumping at the bottom of all the deep rock caverns now used for oil storage that have been excavated in water-bearing rock.

An added advantage will be obvious - protection of the visual environment, since all equipment for oil storage installations can also be placed underground. Assisting with the economics of underground use is the fact that the rock excavated for storage space can usually be sold for use as concrete aggregate (or for other engineering purposes). It was, indeed, the mining of limestone aggregate in Kansas City for almost a century that gave this mid-western city such a head-start in the use of the underground, with almost five square miles of underground space already available for use. Both of these ancillary advantages of using underground space are important in Canada but the potential saving of energy is paramount.

Geoscientists will be familiar with the normal pattern of ground temperature variations - the decreasing amplitude of temperature variations as depth increases, diurnal variations close to the surface, annual variations as depth increases further until at about 10 m below surface level, in temperate climates, the ground temperature becomes sensibly constant. This constant ground temperature is close but not exactly equal to the local annual average air temperature. In southern Canada this will be found to be something like

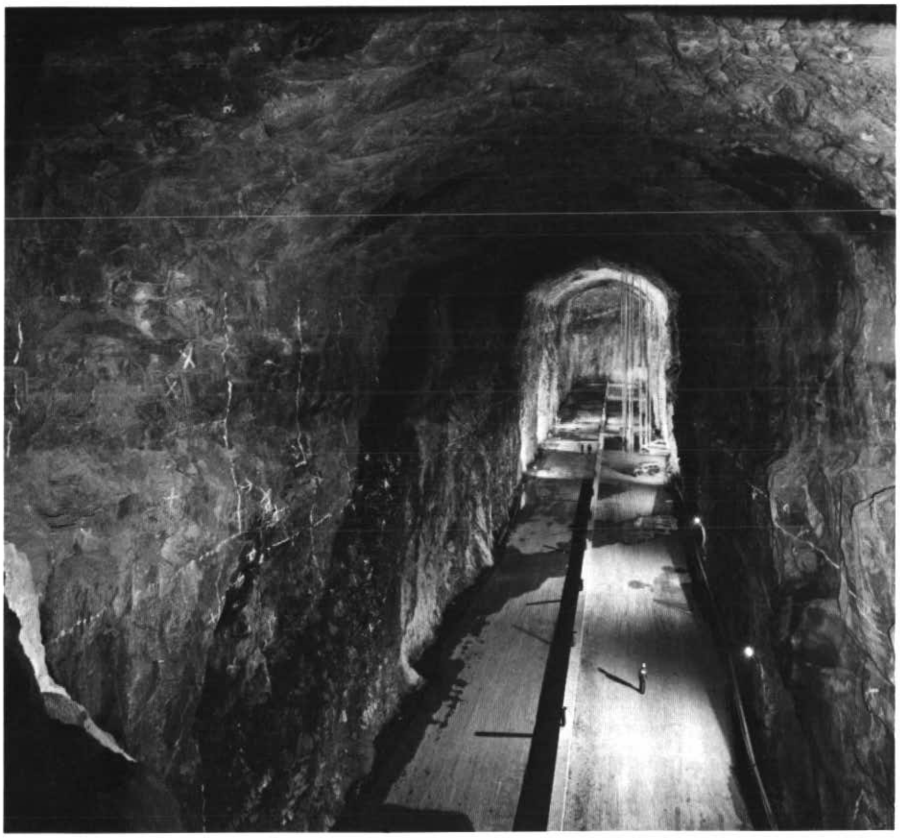

Figure 1.
Typical Swedish rock cavern for storage of petroleum products. (Photo courtesy of Skanska Cementgjuriet.)

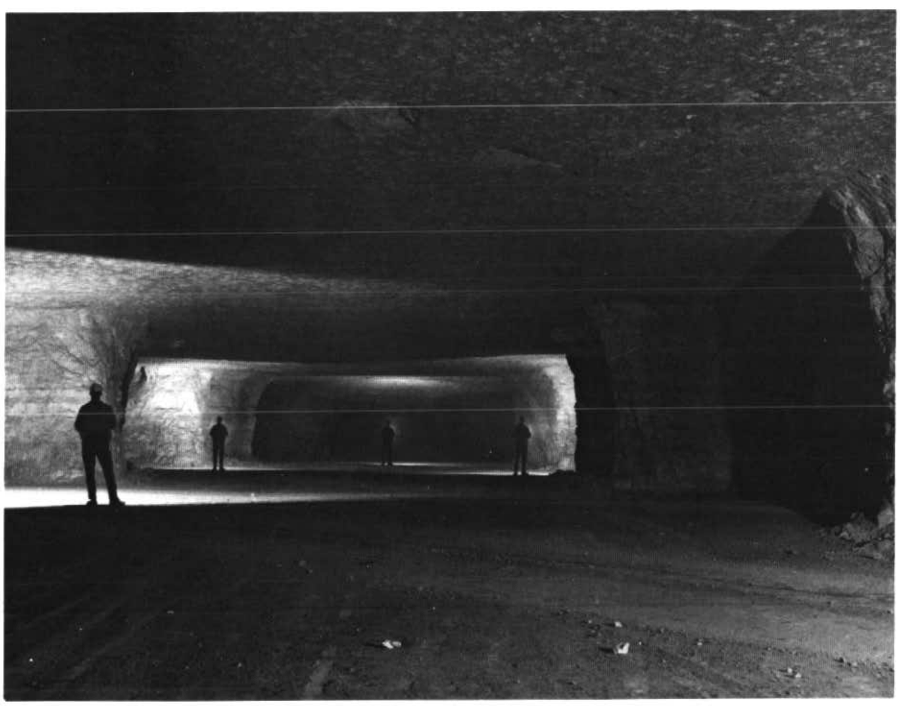

Figure 2.
View inside one of the disused mined-out areas at Kansas City in the Bethany Falls limestone. This shows a level floor and competent rock roof; developments noted in the text are in areas such as this. (Photo coutesy of the Missouri Division of Geological Survey and Water Resources, Jerry D. Vineyard.)

10°C. If this temperature be compared with the comfort temperature required in buildings (say 22°C), it will be at once obvious that to bring underground space up to comfortable temperature, the heating load will be constant throughout the year thus giving economy in the installation cost of heating equipment. No cooling equipment will be necessary for "air-conditioning" in summer months. Energy requirements for operation will be greatly reduced from what is required for buildings on the surface.

Correspondingly, and of even more significance from the point of view of energy conservation is the greatly reduced amount of energy to provide chilled space for "cold storage" below ground. Again, a constant demand throughout the year with the added advantage that, if refrigerating equipment stops for any reason, the warming up of the chilled space until service is restored will be much slower than for even the best of surface plants, approximately in the ratio of 1°F per day, compared with 1°F per hour at the surface. Stand-by plant can therefore be minimised, with further savings.

That these are not just theoretical conclusions has been well shown by experience at Kansas City. The city is located within a broad belt of Upper Pennsylvanian marine beds circumventing the Ozarks, dipping generally to the northwest at less than 20 ft per mile. The upper third of the total thickness of 900 feet are normally exposed in the region around the city, and in the city itself, rolling topography giving many good exposures. Strata are generally alternating shales and limestones, one of which - the Bethany Falls limestone - has been the source of local limestone supplies for the last hundred years, recently for use as concrete aggregate. The result of this activity is the existence of 13 mined-out areas, almost horizontal and with ample headroom, beneath the developed city area (Fig. 2). All have direct access from city streets. The total area of mined out space is about 140 million square feet and this is steadily increasing. About one square mile, in total, of this space has already been developed for industrial purposes, with offices, storage areas, a laboratory, small factories, and large cold storage facilities. About 2,000 people work in this small "underground city" in complete comfort.

Some isolated experiments elsewhere, in using existing underground spaces for appropriate purposes, had taken place in the years following the end of the second world war. It was, however, the pioneer factory of Amber Brunson, opened in 1955, that directed attention to the unused potential of the space beneath Kansas City. For instrument manufacture, Mr. Brunson needed vibration-free and dust-free space; he hit on the idea of going underground. He had the space he needed initially specially excavated, sale of the excavated rock being an unexpected bonus. Underground developments in Kansas City since that time have been generally through the use of existing mined-out space, all recent mining being carried out with carefully located pillars left in place in order to give convenient floor areas. The Bethany Falls limestone is underlain by the Hushpuckney shale which therefore forms the floors of most of the mined-out areas. Some expansion has been experienced with this shale but research on this problem is in progress (Coveney and Parizek, 1977).

Perhaps the most remarkable part of the Kansas City underground is that now used for cold storage plants. One of these is the largest in the United States; together they provide about ten per cent of all the cold storage space in that country so it is not surprising to find that some of the plants have their own, underground, railway sidings. Their efficiency, and energy conservation is shown by such figures as these: installation costs expressed as dollars per square foot - above ground $30, underground $8 to $18; operating costs also per square foot - above ground $0.12, underground $0.010, use of energy being in approximately the same proportions (Bligh and Hamburger 1974). The same authors give the following figures for the actual construction of Mr. Brunson's plant, and its operation, with estimates of an equivalent facility above ground: Heating units - (Btu/hour) 75,000 for the plant, 2,000,000 for an above ground plant; and operating costs, in the same order - $3,200 per year, and $50,000 to $70,000 per year.

The geology of the Kansas City area is well suited to the development and use of underground space but it is far from being unique. Examples could be cited from around the world showing comparable imaginative use of the underground, in every case with appreciable saving of energy as compared with similar installations at the surface. In Poland, for example, the old disused salt mines at Wielczka now contain a 500-bed hospital for patients with respiratory complaints, following the success attending an experimental 35-bed sanitorium, a striking contrast to proposals to use other salt mines for storing atomic waste material. The London Clay has enabled the city to develop its unrivalled system of underground railways, use of the "tube tunnels" for other purposes (as during both wars) providing another illustration of underground use. Libraries, completely underground, have been constructed in quaternary deposits at Oxford (England), and at the University of Illinois. The University of Minnesota (Fig. 3) has recently completed an underground bookstore and administration office building well instrumented so that its detailed performance can be checked. The Mormon Church has used the granite of the Wasatch Front near Salt Lake City for its new Archives, security here being another added feature, the entire installation being deep in the solid rock, entered by protected doorways.

The Churchill Falls underground power station ranks as one of Canada's greatest underground caverns (Fig. 4), although its construction was dictated by engineering design considerations rather than by the need for energy conservation. The main hall is 150 ft high, 80 ft. wide and about 1,000 ft long, a veritable cathedral of power. At North Bay (Fig. 5) is another unusual underground installation, the Canadian NORAD station corresponding with the U.S. base at Colorado Springs. About 300,000 cubic yards of competent grantic gneiss was excavated in providing the approach tunnels, main halls and ancillary rooms for this vital defence project. The two main halls are 400 ft long, 60 ft high and 45 ft wide, large enough to have erected in one of them a complete three-storey steel framed building (Margison, 1977). Underground garages of distinctive design have been built in Quebec City and at Queen's University, with benefit to the visual environment in both cases (McCahill, 1977).

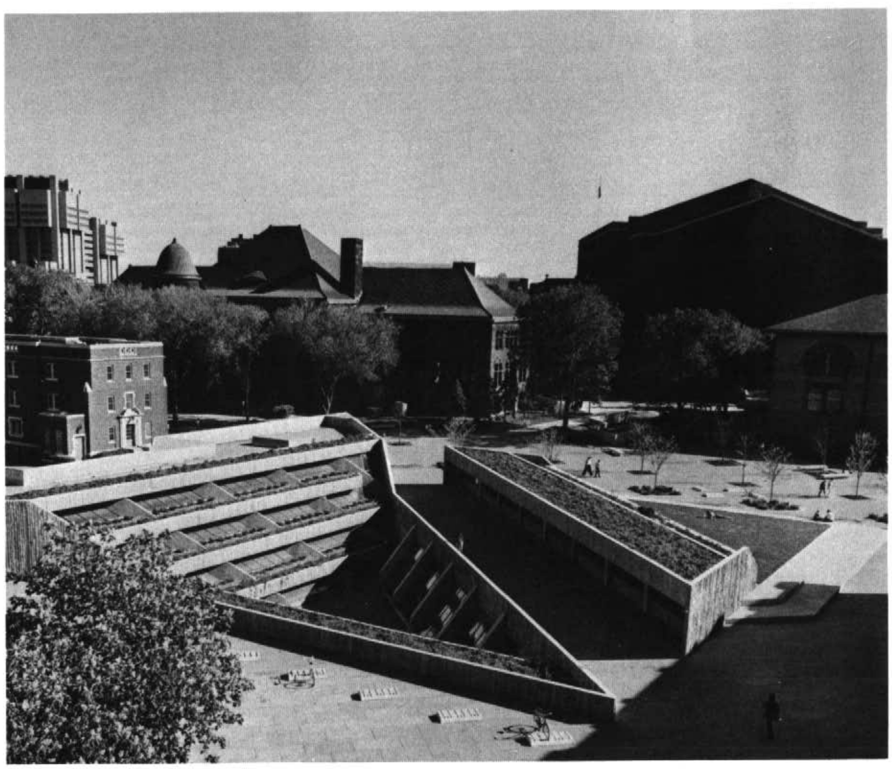

Figure 3.
Underground three-storey Bookstore and Office Building on the main campus of the University of Minnesota, Minneapolis (opened 1977). (Photo courtesy of the University of Minnesota.)

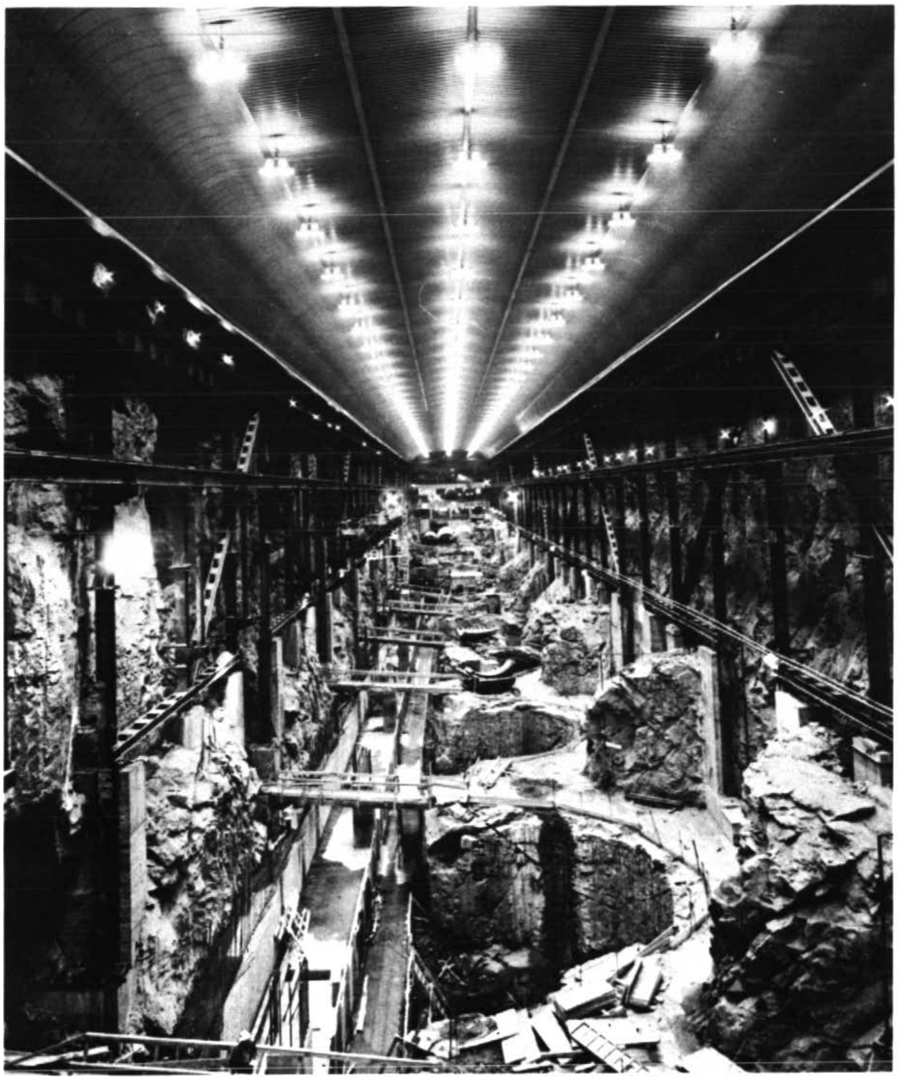

Figure 4.
Underground Power Station for the Churchill Falls Project, Labrador (under construction). The man in the foreground gives the scale. (Photo courtesy of Churchill Falls (Labrador) Corporation.)

Toronto, Montreal and now Edmonton have demonstrated the advantages that accrue from placing rapid transit systems underground. And the extensive underground shopping centres that are now to be found in leading Canadian cities, following the lead of Montreal, not only show how convenient use of the underground can be but provide a vivid answer to those who aver that they "couldn't be happy underground". None of these examples, however, had energy conservation as the controlling factor in design. This challenge remains. Let two examples be cited to show what Canada could do.

The Government of Canada has indicated that new accomodation for the Public Archives of Canada, so justly renowned, must soon be provided. Archival material must be protected from sunlight and desirably kept at constant humidity and temperature, conditions ideally provided by the use of underground space. Archives must steadily expand as holdings increase. With good planning, provision for almost unlimited expansion, without any interference with regular use of existing space, can be provided underground. The Paleozoic limestone of the Ottawa area, while not perhaps ideal, can provide all the space necessary for the Public Archives. The Mormon Church in North America, Sweden and Norway have all shown how suitable underground space is for archival purposes. Canada should follow their example, if only to show how energy can be conserved in a major governmental facility.

The city of Hamilton backs on to the Niagara Escarpment the natural beauty of which must so rightly be preserved. The Toronto region is already having to bring in aggregate for concrete from points up to 80 miles away. And one of the current tragedies of Canadian land use is the erection of single-storey

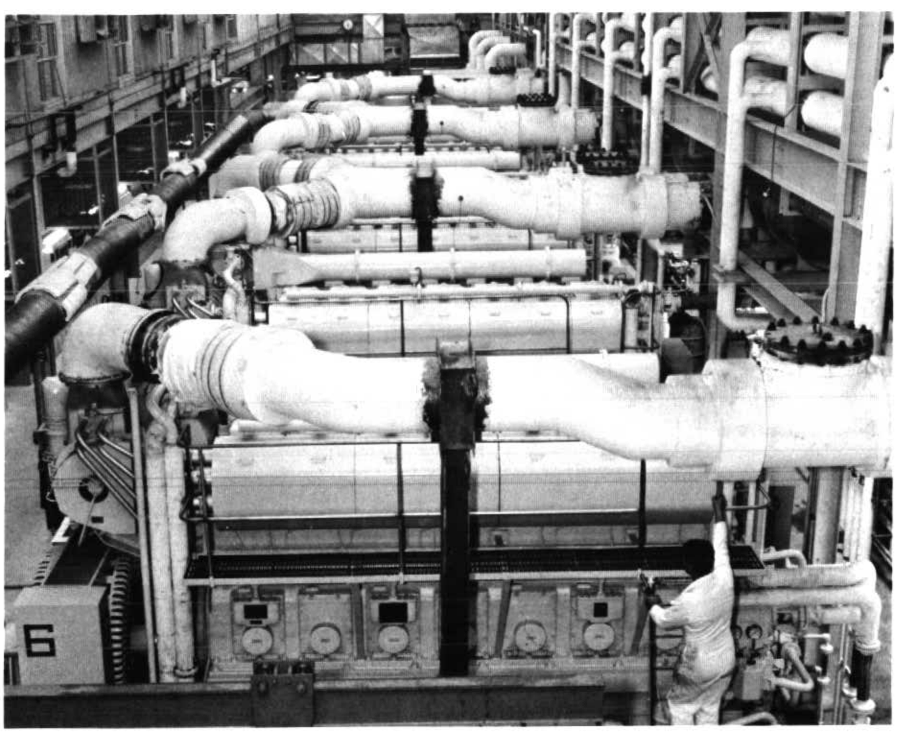

Figure 5.
Underground Power House at the North Bay NORAD centre. (Photo courtesy of the Department of National Defence.)

industrial buildings on the irreplaceable Niagara fruitlands. Combine an approach to all three problems by tunnelling into the Escarpment at an appropriate elevation, using the excavated limestone for concrete aggregate thus eliminating the need for surface quarrying, and then use the carefully mined-out space for industrial purposes instead of using up more of the invaluable fruitlands. In so doing, great savings of energy will be achieved - for the industrial operations and in the procurement and shipment of concrete aggregate. Hamilton could be for Canada what Kansas City is in the United States of America.

These are but two of the challenges presented in Canada by the possible use of underground space. In every part of the country, there are similar opportunities for energy conservation in future building once the concept of using underground space has been accepted. In every case, however, the possibility of going underground depends absolutely upon the local geology. Thus it is that Canadian geoscientists have almost a responsibility to see that knowledge of local geology is always used in planning, especially so when there is any possibility of building underground instead of on the surface.

As use of the underground progresses in Canada, useful information about the geology of excavated spaces will steadily become available. Much of this will be as expected but there will always be the possibility of finding something new and unsuspected if such excavations are studied by geologists. It is salutary to recall that the riddle of Rhine Graben was solved, at least in part, by an observation made by Hans Cloos as he studied the excavation of a small railway tunnel under the Lorettoberg in Freiburg. Strong support for this suggestion is given by the fact that at the joint GSA-GAC annual meeting to be held in Toronto in October 1978, there will be held - for the first time, it is believed - a symposium on *Geology beneath Cities*.

References

Bennet, D. and T. P. Bligh, 1977, The energy factor - a dimension of design: Underground Space, v. 1, no. 4, p. 325-332.

Bergman, M., 1978, Storage in excavated rock caverns: Proceedings of Rockfall '77, Pergamon Press, 3 volumes, 832 p.

Bligh, T. P. and P. Hamburger, 1974, Conservation of energy by use of underground space, legal, economic and energy considerations in the use of underground space: Washington, National Academy of Sciences, p. 103-119.

Coveney, R. M. and E. J. Parizek, 1977, Deformation of mine floors by sulfide alteration: Assoc. Engin. Geol. Bull., v. 14, p. 131-156.

Margison, A. D., 1977, Canadian underground NORAD economically achieved: Underground Space, v. 2, no. 1, p. 9-17.

McCahill, G., 1975, Underground parking at Queen's University; Underground Space, v. 1, no. 4, p. 347-353.

Parizek, E. J., 1975, Geological setting of Greater Kansas City: Proc. Symp. on the Development and Utilization of Underground Space, Univ. of Missouri, KANSAS City, p. 9-23.