터널과 지하공간, 한국암반역학회
Vol. 2, 1992, pp. 28~49

Rock Mechanical Problems in the Construction of the Montreal Metro

Gérard G. Gosselin[1)]

Introduction

Montreal is an island approximately 50km. long by 16km. wide dominated by the Mount-Royal, which is 229m. high. The St Lawrence River is on its south shore and the Rivière-des-Prairies, on the north shore. In order to have a better understanding, the following is a brief survey of the geological history of the region.

The island of Montreal is part of the region of the St Lawrence lowlands. The history of its rock formation of the area can be divided into three phases, each one separated by a long period of erosion. The first stage covers the precambrian period. Igneous rocks from the Laurentian mountains were formed during that period. They constitute the base over which recent sediments have deposited.

The second stage is characterized by the marine submergence from the precambrian period. During that period there was the formation of sediments, calcareous, dolomite and sandstones. These formations are the same for the whole of the island, except for the Mount-Royal. The last stage consists of igneous activities which formed the Mount-Royal and small hills in the region.

The tectonic of the region can thus be summarized. The sediments were submitted to foldings of a large radius. The bedrock has a slight dip, except in zones of minor folding or close to faults. The axis of the folds are parallel to the regional direction of the Appalachians and appear to be the result of compressive forces produced during the formation of those mountains.

The overburden dates back to the pleistocene period, which is characterized by the continental glaciation. At one time the ice cover reached 300m. high. The glaciers have deposited eroded material. The ice cover caused a depression, allowing deposits of clay coming from the St Lawrence valley. An inverse isostatic readjustment caused the reemergence of the continent and the

* 1992年 6月 接受.
1) Engineer, Spino Construction Company Ltd., Montreal, Quebec, CANADA

withdrawall of the Champlain sea, leaving coastal deposits of sand and gravel in various locations.

The rock of the mountain and its immediate surroundings is of granite. Most of the island consists of sedimentary rock in horizontal layers. On the east and north of Mount-Royal, we find limestone of relatively good quality. Further east of the island it is shale. Closer to the St Lawrence River, it is soft shale. When the shale is wet it stands turn into dust. Fortunately, in many areas on the island there is little overburden. It is then advantageous for tunnelling.

Preliminary Considerations

At first, two single tunnels were considered. They would join at a station with the platform in the middle. It was considered too costly and rejected. Then the idea of a single tunnel, including the two lines, was considered. The tunnel would be 7.1m. wide × 5m. high. It would enter the station, which would be 13.4m. wide × 6.3m. high. Each side of the station would have a platform.

However, two stations had to be modified due to the bad rock conditions. At one point before the station, one train dips and passes under the incoming line to arrive at the lower level in the station. The width was now reduced to one line and one platform.

At the Berri Demontigny station, line 2 crosses above line 1. In two other transfer stations, the two lines superimpose and merge, allowing passengers to change line without changing levels.

Tunnelling in Rock

As previously mentioned, in many areas the rock is close to the surface i.e. 3m. to 10m. The line of the tunnel can easily be reached by a ramp or a shaft when there is no space available for a ramp. Transportation to and from the tunnel is direct. All equipment and personnel can go in and out as deemed necessary. The movements are not hampered by waiting to be hoisted or lowered by a crane. There is no loss of time and it saves the use of a large crane.

The advantage of driving a tunnel is that while the work is enprogress it does not interfere with the city traffic. In the case of open cuts, the streets have to be closed for long periods of time. The tunnel is ideal for the choice of a route. It can pass near and sometimes under buildings to reach a designated area. In open cut, the line is more or less limited to the streets. When studying a route, the designers having on hand all the information on the quality of the rock, can choose the most advanta-geous route in line and grade to keep the tunnel in sound rock.

Birth of the Initial System

In 1961 the municipal authorities voted credits of $132,000,000.00 for the construction of 16km. of line, 17 stations and the necessary equipment for a subway. The Public Works department became responsible for the design and supervision of the construction. The R.A.T.P (Régie Autonome des Transports de Paris) sent two engineers to serve as consultants.

One feature is that the trains run on rubber tires. The R.A.T.P. had experienced on an extension of their subway and was satisfied with the results. It gives a smoother ride, is less noisy and can negociate slopes of 6%. When there is a flat tire, the auxiliary steel wheel will come to rest on a rail. The train can then reach the garage. In order not to interfere with the traffic during its construction, line 1 was located north of Ste Catherine street and line 2 between St Denis and St Hubert streets.

In general the stations were close to the surface. This minimized the amount of escalators. When leaving a station, The train dips on a 6% slope helping its acceleration, therefore using less energy. It quickly attains the speed of 50km. per hour. As it rides up the slope of the next station the train looses speed, the current chopers return power to the line, a 25% economy, the conductor then applies the brakes to come to a stop.

Beginning of the Project

Work started in April 1962 at various locations. As soon as plans and specifications were ready, tenders were called. In a section would include a certain length of tunnel and two stations in tunnel. The work started by a ramp with an average slope of 15%. One ramp was as much as 22%. As the rock was uncovered, drilling and blasting started. When there was 2.5m. of rock cover over the access tunnel, it was then driven to reach the axis of the main tunnel. Widening of that area was done so as to facilitate further movements of the equipment. Rock bolts were installed to insure safety and stability. The first ramps were drilled with air tracks, their booms angling as much as possible to the horizontal. It was ackward but it did the job. Before each blast all the equipment was removed. Once 75m. of tunnel had been excavated, the equipment remained underground.

Drilling Operation

In the beginning, the drilling jumbos consisted of tubular scaffolds, installed on overturned sheet piles, supporting one main platform and two lower side wings. It allowed the miners to drill the round with pneumatic drills G.D. 63 attached to air legs. The opening left in the middle of the jumbo allowed the passage of trucks and loader. It was dragged into place by the loader.

A round consisted of 65 to 68 holes 30mm. dia. × 2.9m. The holes were loaded with dynamite cartridges, Forcite 40% 25mm. × 200 mm. Perimeter holes were loaded with Xactex cartridges 12mm. dia. × 600mm. to reduce the overbreak. L.P.V. electric blasting caps with periods from 0 to 20 were connected to a main line and onto a blasting battery. This fractioned the charge so as to diminish the vibrations. Two 600mm. dia. electric axial fans blew air through sheet metal ducts into the face. After 20 minutes of blowing, the face was clear of smoke. When reaching 350m. of tunnel, another fan was installed on the line to maintain the volume of air. The advancement was then 6.0m. per day.

Pre-Survey

Prior to all blasting operations, a pre-survey was made along the route. In areas close to buildings and houses, the consultant would make his recommendations with respect to the limits of permissible vibrations. He would also check the contractor's loading pattern. When the tunnel approached these buildings, some seismographs were installed and recordings of the blast taken. The same would apply to a nearby house. If the vibrations were in excess, he would immediately notify the contractor to modify or reduce the charges. Those recordings were kept for future possible claims.

Mucking Operation

In the first tunnels, loading the muck in trucks was done by and Eimco 105 overhead loader. Aveling Barford trucks did the hauling from the tunnel to the surface and dumped onto a muckpile, inside the worksite. It was then reloaded on highway trucks and disposed in designated areas. This method of rehandling the muck at the surface, limited the amount of vehicles in the tunnel and avoided delays in the operation. The work in the tunnel was not affected by city traffic.

As time went by, other types of loaders were used. The Eimco 123 side dump loader was next used. Then the Caterpillar 977 side dump loader became in use. The last largest loader used was the Caterpillar 983 side dump, specialy conceived for underground work at James Bay. Highway trucks, equiped with oxy-catalist scrubbers, were used in the tunnel. They replaced the Aveling Barfords we had.

At the start of the mucking cycle, the miners would sound the roof with scaling bars. Any loose rock was wedged and pulled down. Meanwhile the muck pile was sprayed with water to keep the dust down. When the scaling was done, the mucking operation would begin. The miners would check the face in the same manner. The surveyors would then give the line and level and mark the face. The face would then be ready for another drilling cycle.

On one section we transported the muck to a vacant land where an impact crusher was installed. The crushed stone was loaded into a 100 ton bin by a conveyor. Trucks were reloaded with crushed stone and delivered to another section where stone backfill was required.

The Shaft Method

A ramp could not be used for some sections. The access had to be made by a shaft. It was usually located within the station. The shaft would be sunk to the bottom which was then expanded to allow equipment to be lowered. The same loader would load muck in trucks. They would haul the muck to the shaft and dump their load into large buckets sitting in a pit. The crane raised the bucket to the surface and empty the bucket onto a muckpile. Highway trucks were loaded and hauled the muck to a designated area. At one site two cranes P&H Kobe of 90 tonnes capacity disposed the muck in this manner. With this installation, an advance of 26m. per day was attained with two shifts.

Improvements

In the beginning, drilling was done with pneumatic drills attached to air legs. Eventually the jumbos were improved. They consisted of a steel frame, a large solid deck for the top part and a bottom deck to also receive an air receiver, headers for air and water, line lubricators. Each jumbo carried four G.D 93 pneumatic drills, mounted on slides with hydraulic booms. Two such jumbos were placed side by side. They now had front wheels and were manoeuvered as a trailer by the loader. With this drilling power and a large loader, the rate of advance greatly increased.

A round now consisted 55 holes of 45mm. dia. × 3.35m. It included 6 62mm. dia. holes not loaded. They were used for the burnt cut.

We then saw the appearance of a Jarvis Clarke carrier with two Tampela hydraulic drills, mounted on slides with hyraulic booms. Later Atlas-Copco came out with a larger carrier and with heavier drills.

The hydraulic drill penetrates faster, requires less power, is less noisy and does not produce fog like the pneumatic drill. The only drawback is that it requires another piece of equipment to load the explosives in the face. Security forbids to load from a manway resting on the drill booms. To overcome this, an extra boom with a basket is mounted on the carrier to do the loading at the upper part of the face.

Excavation of Station in Tunnel

A station is 155m. long, 13.4m. wide × 6.3m. high. When the tunnel reaches the station, the drills are angled upwards to reach the crown of the station. Drilling will then be maintained at the crown height, throughout the length of the station. The width of the tunnel is kept the same. The advance is slower, since shorter rounds are drilled.

Upon reaching the end of the station, the jumbo will be turned around and drill the part left out. The second stage will be to slash the sides. A slash is taken on both sides, perpendicular to the axis of the station, When the opening is long enough for the jumbo, drilling will be done longitudinally on both sides, so as to widen the station to its final dimensions. The installation of rock bolts will follow closely the face.

Tunnel Support

In general roof support consisted of rock bolts, placed at regular interval. They consisted of 20mm. dia. × 2.66m. rods, threaded at both ends to receive a cone and a shell at one end serving as anchorage and a bearing plate 150×150, a washer and nut at the other end. When the bolt was installed in limestone, it held firmly.

However, in shale it was a different matter. After a certain period, slippage would occur. Retorquing them had to be done. Again later on, more slippage occured. In certain places, there was no more thread left to retorque them. After discussion with the authorities, we suggested to use deformed bars 25㎜. dia., threaded at one end to receive the bearing plate. The other end would be anchored with resin cartridges. Three cartridges would be inserted in the hole, the bar pushing them at the bottom of the hole. The bar would pierce them and be torqued with an impact wrench, till it could not turn anymore. The bearing plate was then installed and torqued till refusal. No more slippage was noticed.

In some instances, the rock was badly fractured. Steel supports were needed. As soon as the mucking of a short round was completed, a steel rib was installed, secured in place by tying it to the previous one with tie-rods and spreaders. Wood lagging and blocking were installed between the rib and the rock. Concrete was poured in blocks at the beginning of the arch. Under those conditions, an advance of 1.5 to 1.8m. was attained per day.

Support with Shotcrete

In the section Verdun de l'Eglise, another difficult situation arose. After sinking the 24.3m. deep shaft and widening the bottom, rock bolts were installed to provide roof support. A little further in the tunnel, this type of support proved to be inadequate. After investigation it was dicided to proceed with steel ribs. It was soon found out that progress was much too slow and costly. Further omore, the workers did not have enough time to remove the muck and install a rib. Shortly after the beginning of the mucking, some rock would fall. It was definitely dangerous. The foreman stated that if something could hold up the roof long enough to remove the muck, they could install the rib.

We then thought that if a first coat of shotcrete be applied from the muckpile immediately after the gases were cleared, it may then give enough time to remove the muck. A second coat of shotcrete could then be applied after all the rock has been exposed. It turned out to be the right solution and it allowed to obtain an advance of 3.5m. per day. The shotcrete held up well and we had no further worries for the stability of that section.

Tunnel under the St Lawrence River

Line 4 begins at the St-Denis station, passes under the old section of Montreal, dips under the St-Lawrence River, emerges on Ste-Hélène island in the station built in open cut. It then plunges again under the St Lawrence River and the St Lawrence Sea-way channel. It emerges on the south shore into the Longueuil station.

On the north side, a ramp was excavated in a park, north of Craig street. Soldier beams and lagging were used to support the ground. The bedrock was excavated down to a portal and an access tunnel driven to reach the axis of the main tunnel. The rock was shale and ribs had to be installed at Various locations.

When the tunnel reached the edge of the river, an horizontal test hole had to be maintained at least 15m. ahead of the face, to detect any important infiltration of water. This way, it gave a warning and a possibility to grout through more holes to seal off the infiltrations.

Prior to the tender, an attempt had been made to take two rock cores from a barge. Unfortunately an accident happened. The barge capsized and two men were drowned. No further attempt was made. There was then no information on the rock for the section under water.

This is one reason why the rock cover was kept at 9m. thick. Facing the unknown for the rock conditions, the contractor asked to sys-tematically install ribs at 1.5m. interval for a great part of the section under water. He argued that installing ribs at random places was slowing down the advancement and it was definitely safer to install them systematically. The B.T.M. agreed although it meant an extra cost of $1,000,000.00. Even though other problems came up, the contract was finished on time.

Comments on the Payment of Rib Support

For a contractor, the installation of ribs is a necessary evil. We do not like to install them but there is no choice when the rock is bad. They become costly in loss of time. All the personnel and equipment are iddle, except for the workers and a mobile crane. The compensation is a pre determined price included in the tender. It barely covers a third of the actual cost. Many representations were made but to no avail.

When preparing his tender, the contractor must estimate the length of bad rock he may encounter. If he offsets his unit prices to cover the extra cost, chances are that he will not get the job. Some contractors thought that the fixed unit price paid by the owner was sufficient and tendered accordingly. They were successful and did the jobs. Some of them are no longer contractors. It may not be just for that reason but it helped.

My suggestion for a fair compensation would be to determine each section of tunnel a) in rock with rock bolts b) in rock with ribs. It would be the responsibility of the owner to determine which condition is applicable. The contractor would then establish a unit price for each condition. The real cost would then be included in the proper items.

Overbreak

When driving a tunnel that will be lined with concrete, it is important that when driving, to follow the contour line. If there are protrusions more than 500mm. they have to be removed. It is done with an hydraulic breaker, mounted on the boom of a small tractor. When they are larger, drilling and blasting will be necessary.

In general a gauge is built 200mm. smaller than the actual contour. Flexible metal strips are attached to this gauge, which will reach the contour line. The gauge is set on tracks which are set at the proper line and level. As it passes along, it will locate the protuberances which will be marked by paint. They will then be removed as previously described.

In limestone of 20 Mpa or more, the overbreak is well controlled. It will mean less waste of concrete for the overbreak. Incidentally there is no separate item for this concrete. The contractor has to estimate the quantity of excess concrete and include it in his tender.

In the shale the rock breaks in steps causing a large amount of overbreak. This excess may as high as 100% of the theoretical quantity. Care has been taken when the tunnel was excavated. Special dynamite was used. Yet that type of rock will break in steps. In one instance when a station was concreted, it was seen that a man was standing on the form barely reaching the crown. One can well imagine the volume of concrete that went into that pour.

Safety

No matter what size the project is, a fatality is always to be deplored. At the beginning, the security rules were not stringent. The main complaint was insufficient ventilation. With time, new rules came into effect. The safety code was revised and new rulings issued.

Ventilation now requires : 5.5 cu. m./man/min.
15 cu. m./s.m /min.
for diesel equipment 5.5 cu. m./ kw/min.

If there is more than one piec of equipment, the first piece is 100%, the second piece is 75% and each additional piece is 50 %. Air samples are taken daily and tested for the content of various gases.

The rules tripled the fresh air requirements. An engineer has to prepare a ventilation plan. It will show the installation of ventilators, their capacity, the size and type of ducts, the capacity of the system and the proposed equipment to be used underground.

The rules for storing, transporting and handling explosives and caps became more rigid. During the day they are stored in special cache on the site. A special vehicle will transport them to the face. At the end of the day, the supplier will pick up what is left and store it in his powder magazine. A record of the consumption of the explosives must be kept. Government agents verify this record. The powder must have a license.

Fire extinguishers are to be in all pieces of equipment, in all temporary buildings at the jobsite and in various places underground. A telephone system has to be installed connecting the office to the working faces of the tunnel. Any person going in the tunnel had to leave his identification tag hung on a board. He would retrieve it upon coming out. Contracts of $8,000,000.00 or more or having 150 men, required a safety officer.

At times, sections of work were closed by an inspector who felt that there was a risk for security. The onus was on the contractor to rectify the situation, have an engineer to examine the corrections. He would verify with the safety code and prepare a report to be submited to the construction security department. It would then remove the seal.

The code also required that no wooden structure could be erected within 12m. from a shaft. At the bottom of the shaft, a heavy wooden partition had to be built near the entrance of the manway. No vehicles with gasoline engines were allowed in the tunnel.

Cave In

On a project of this magnitude, accidents are bound to happen. It does not have to be Murphy's law. If something is bound to happen it will happen. I know the happening of five cave ins, two which I have experienced. One took two months to repair, others varied from four to six months.

In the section Verdun, de l'Eglise, the excavation of the station de l'Eglise was progressing under Wellington street. Steel ribs were being installed immediately after each slash, widening the station. Suddenly, the foreman heard some cracking noises. He felt that the ribs were taking on weight. He examined the blocking and heard more noises. He realized that it had become dangerous and withdrew his crew. He warned the superintendent who in turn asked the city authorities to close the street.

The street was closed, traffice detoured, gas and watermain cut off. The flow of the sewer was also detoured. Barely tow hours after the closure, the cave in happened. There was a hole 25m. long from sidewalk to sidewalk. The W250 × 80 ribs were crushed. The 6m. thick shale could not support itself with the 9m. of overburden. Backfilling the hole was immediately started and was completed by night fall.

Studies were then undertaken. It was decided to make a curtain wall on each side and at the ends, leaving a gap for the sewer main, to be eventually closed with timber. As the material from the cave in and backfill were removed at the floor level of the station, walers and strutts were installed. Upon reaching the rock, shotcrete was applied to seal the toe of the curtain walls. When the rock was exposed, more shotcrete was applied. The bottom was reached without further incident.

This new situation required a major revision in the design of the station. The B.T.M. engineers realized that the shale was too weak to support a regular station and 15m. of backfill. By superimposing the two lines, the station was now narrower, being only one line and one platform at each level. The deepening of the station became part of another contract.

Eventually the station was built as such, the street backfilled. The utilities were restored, the sidewalks rebuilt and the street repaved, well in time for the Christmas shopping, as promised to the Verdun city council.

Obstructions

Most of the obstructions are located in advance. Good planning helps to bypass them without much trouble. However, when there is an obstruction unknown to all concerned and discovered at the last minute, it becomes a source of anxiety.

On contract 2-A-24, the tunnel was progressing westerly from Victoria station. It would be passing close to Place Bonaventure. The construction of this large complex was in progress. By a pure hazard, we found out that one of their huge caisson of reinforced concrete stood at only 3m. from the tunnel. Needless to say that upon learning that the tunnel was being driven that close, they would set up a battery of seismographs, keep all records and later drill cores in the caisson to check for any damage. Meanwhile we had stopped driving the tunnel.

After reviewing the situation, we established a procedure and submited it to our consulting engineer in blasting, for review. It was suggested to drive half the tunnel, on the opposite side of the caisson, with short rounds. This half section was driven till 10m. beyond the caisson. The tunnel was then widened by slashing, to its normal size. No damage was ever reported.

On the same contract, west of Bonaventure station, the tunnel had to be driven under the Windsor station. This large railroad station, dating back to the turn of the century, is classified as an historic landmark. We notified the railway authorities about the tunnel do be driven. At first they were quite upset. We then explained our procedure and the precautions that would be taken. Seismic readings were taken and all blasts were recorded. No damage was detected. After, the railway authorities asked us to build a connection from their station to a passageway, linking with the Bonaventure station.

Conclusion

The Montreal Metro, with its 64.5km. of line, 65 stations, two commuter lines and its large fleet of buses serves well the population, It is one of the finest and nicest subway in the world. It transports over 200,000,000 passengers a year.

In winter it is not affected by snow storms and in other seasons, by rain, nor by city traffic. Some department stores are directly connected to stations. Some large buildings and complexes are also connected by passage ways. At the time of EXPO 67 it transported up to 60,000 passengers per hour.

The bus lines connect to Metro stations. One can park his car at a faraway station, take the Metro, go downtown, do some shopping, eat at a restaurant, go to a theatre or to a movie, even go to a hotel and return to his point of departure without stepping out-side, There are so many advantages. It is convenient, fast and clean. Montrealers like their Metro.

Acknowledgements

The author would like to express his gratitude to the following persons and organizations for their assistance : Mr. Jin Bak Pyon, architect, Mr. Jean Dumontier, architect retired from the B.T.M., the staff of the B.T.M. for the documentation, Mr. Nunzio Spino, engineer, pres. Spino Construction Company Ltd. and the staff in helping to compile the information from the contracts performed on the Metro.

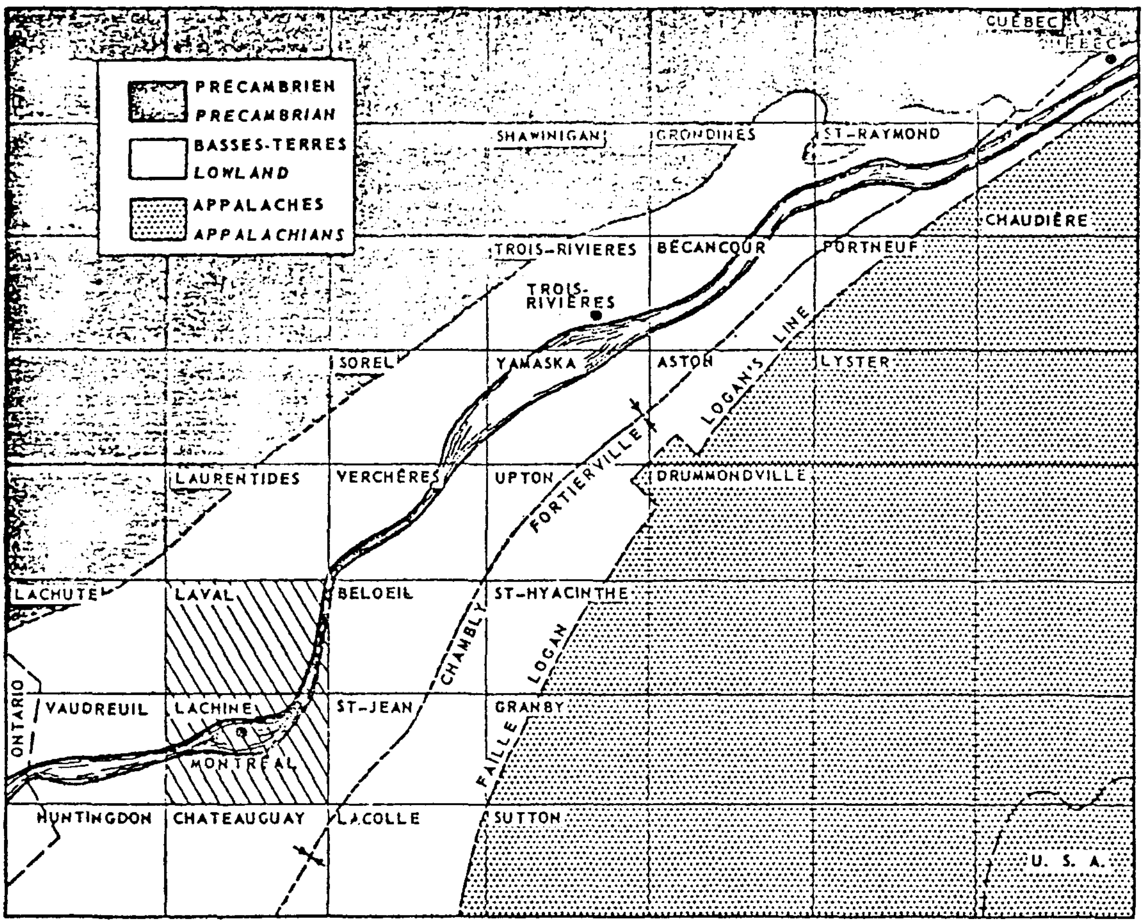


Figure 1 — LOCALISATION DE LA RÉGION ÉTUDIÉE
LOCATION OF MAP-AREA
Extrait du rapport géologique 152 par T.H. Clark (1972)

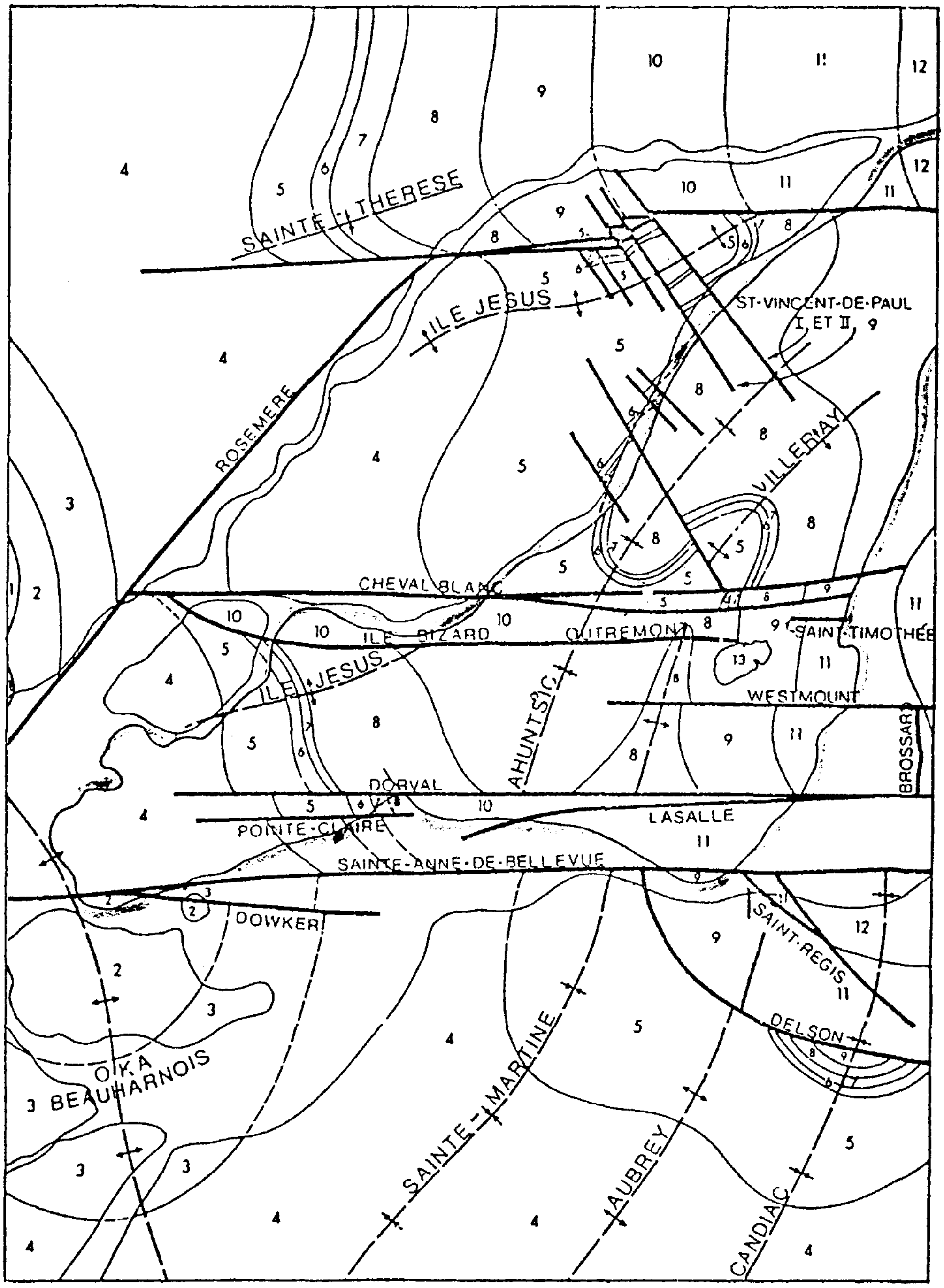


Figure 2

AXES DE PLIS ET FAILLES NORMALES DANS LA RÉGION DE MONTRÉAL.

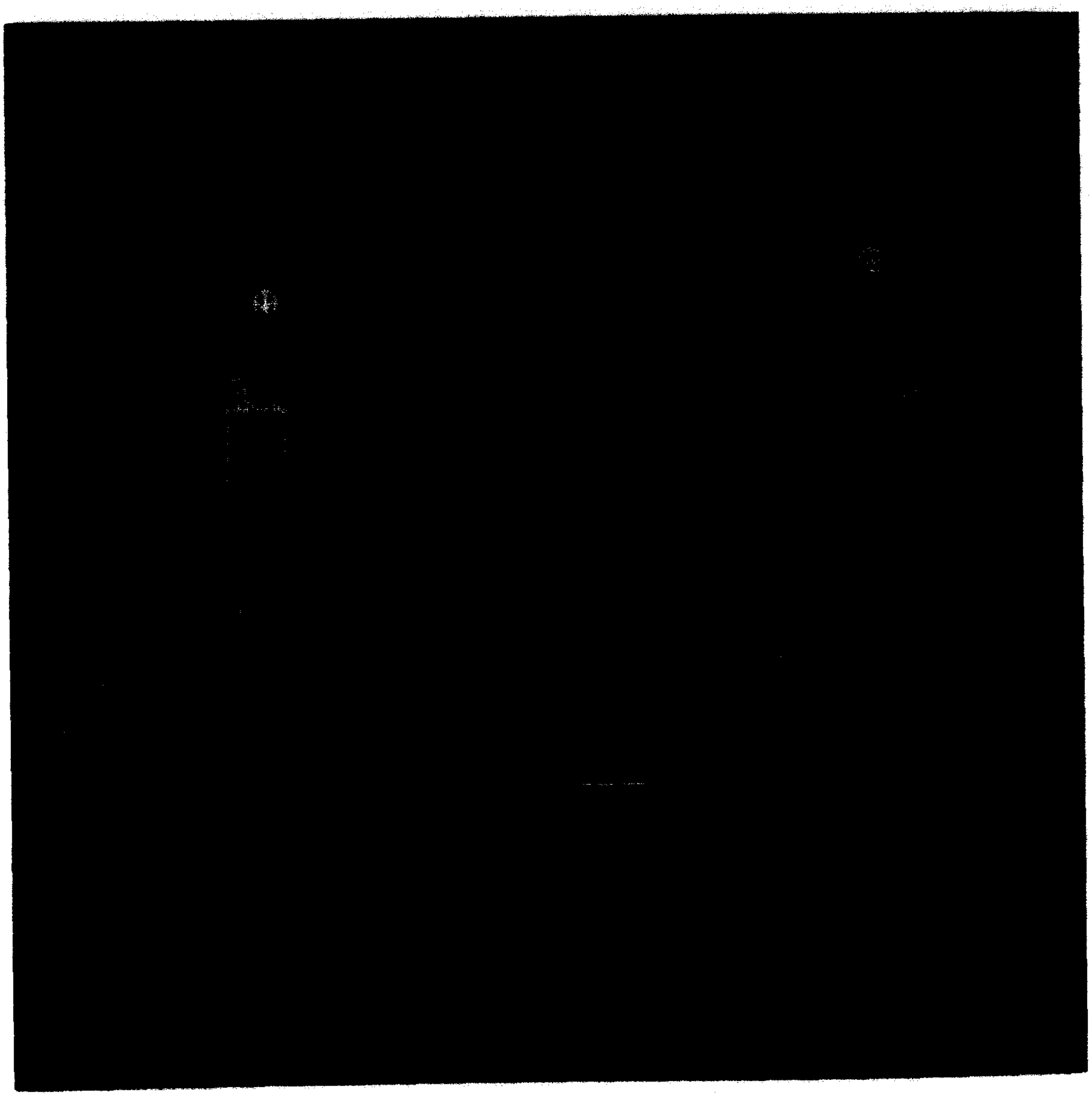
AXES OF FOLDS AND NORMAL FAULTS IN THE MONTRÉAL AREA.

Extrait du rapport géologique 152 par T.H. Clark (1972)

Tab. 1 — RÉSUMÉ DE LA GÉOLOGIE HISTORIQUE DE LA RÉGION DE MONTRÉAL
RESUME OF THE GEOLOGICAL HISTORY OF THE MAP-AREA.

ERES *ERAS*	PÉRIODES *PERIOD*	*Millions d'années écoulées Millions of years age*	ÉVÉNEMENTS *EVENTS*
Cénozoique *Cenozoic*	**Quaternaire** *Quaternary*	1	**Montréal, tel qu'il est aujourd'hui. Glaciation et submergence Champlain.** *Montreal as it is today. Glaciation, and Champlain submergence.*
	Tertiaire *Tertiary*	65	**Erosion**
Mésozoique *Mesozoic*	**Crétacé** *Cretaceous*	135	**Activité ignée. Collines montérégiennes. Failles est-ouest.** *Igneous activity. Monteregian hills. East-west faulting.*
	Jurassique *Jurassic*	190	**E R O S I O N**
	Trias *Triassic*	225	
Paléozoique *Paleozoic*	**Permien** *Permian*	280	
	Carbonifère *Carboniferous*	345	
	Dévonien *Devonian*	395	**Courte submergence.** *Short submergence.*
	Silurien *Silurian*	430	**? Emergence et érosion.** *? Emergence and erosion.*
	Ordovicien *Ordovician*	500	**Orogénie taconique dans les Cantons de l'Est ; plissement des roches sédimentaires. La submersion marine se continue et dépose le Beekmantown, le Chazy, le Black River, le Trenton, l'Utica et le Lorraine.** *Taconic mountain building in Eastern Townships ; folding of the sedimentary rocks. Marine submergence continues ; deposition of Beekmantown, Chazy, Black River, Trenton, Utica, and Lorraine rocks.*
	Cambrien *Cambrian*	700	**Envahissement de la mer ; grès de Potsdam.** *Marine inundation ; Potsdam sandstone.*
Précambrien *Precambrian*	**Récent** *Late*	1500 ±	**Erosion prolongée et continue. Intrusion des granites, des gneiss, etc., qui forment les Laurentides et qui, constituent le substratum de la région de Montréal.** *Long continued erosion. Formation of granites, gneisses, anorthosites, etc., of the Laurentians, and of the basement underlying Montréal.*
	Ancien *Early*	4000 ±	

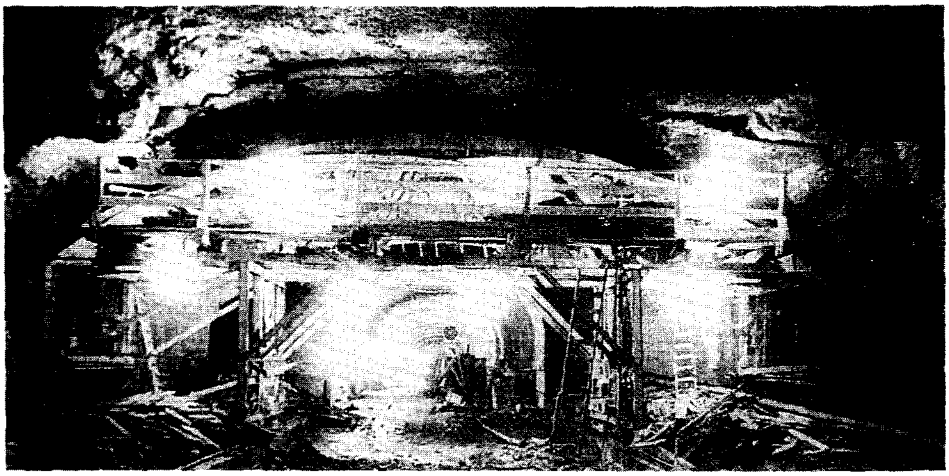
Extrait du rapport géologique 152 par T.H. Clark (1972)



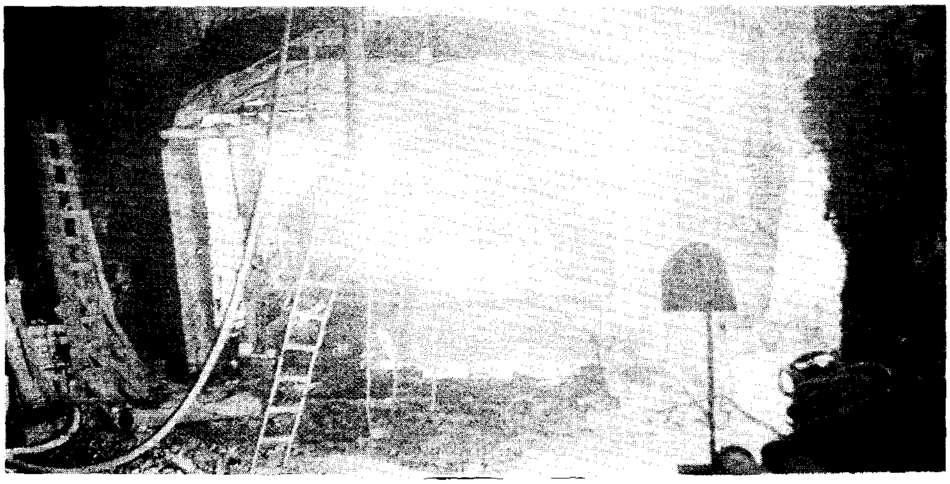
typical profile

drill jumbos

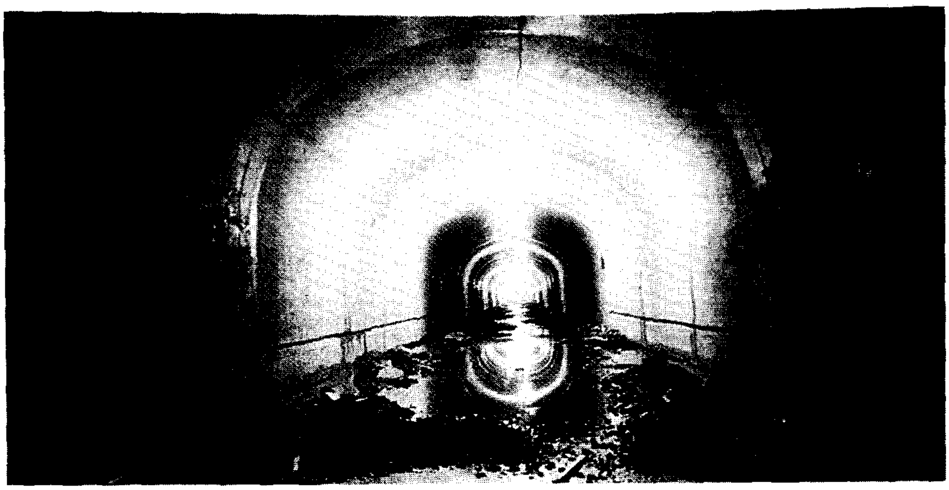
tunnel with steel supports



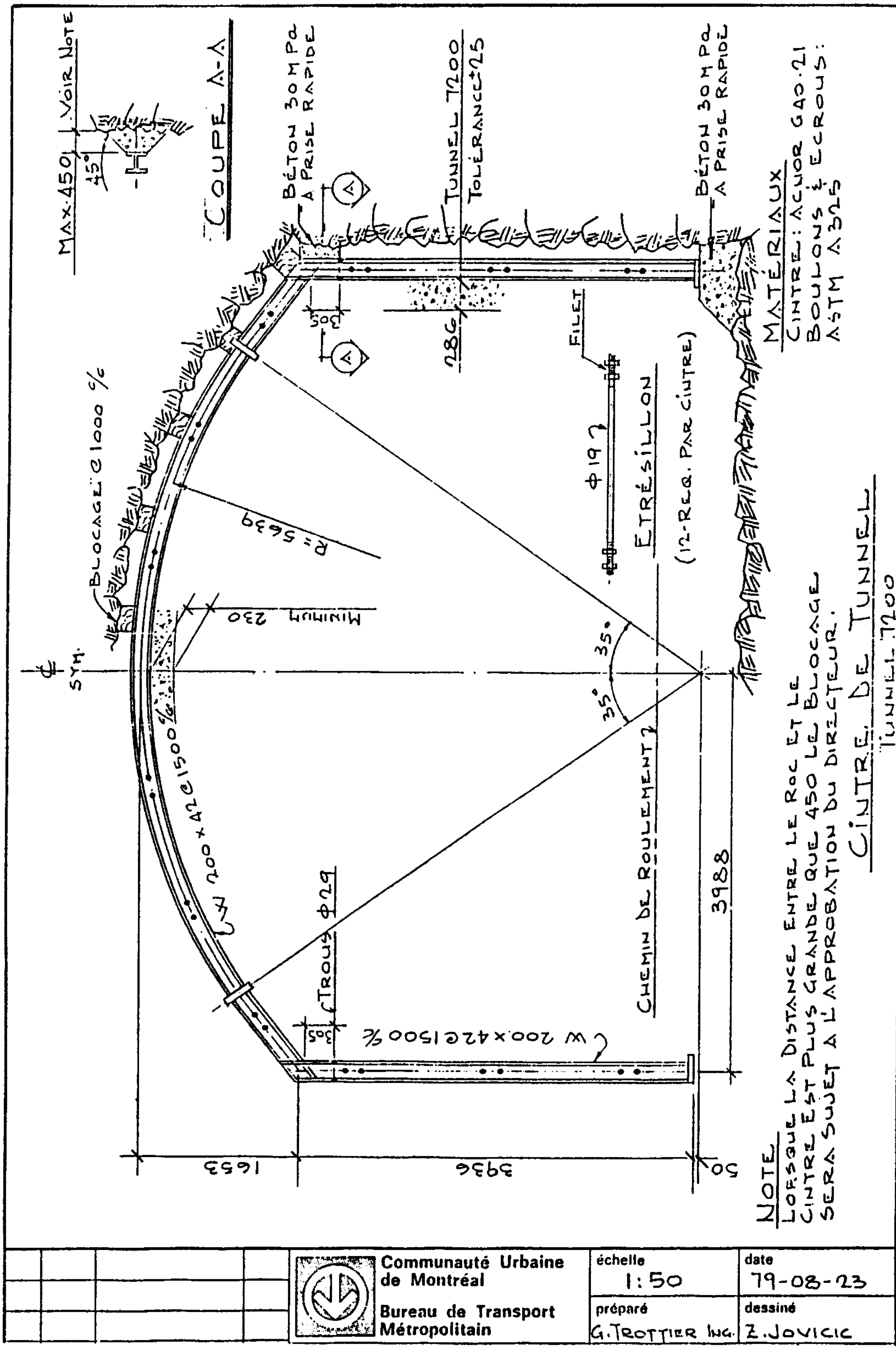
station in tunnel



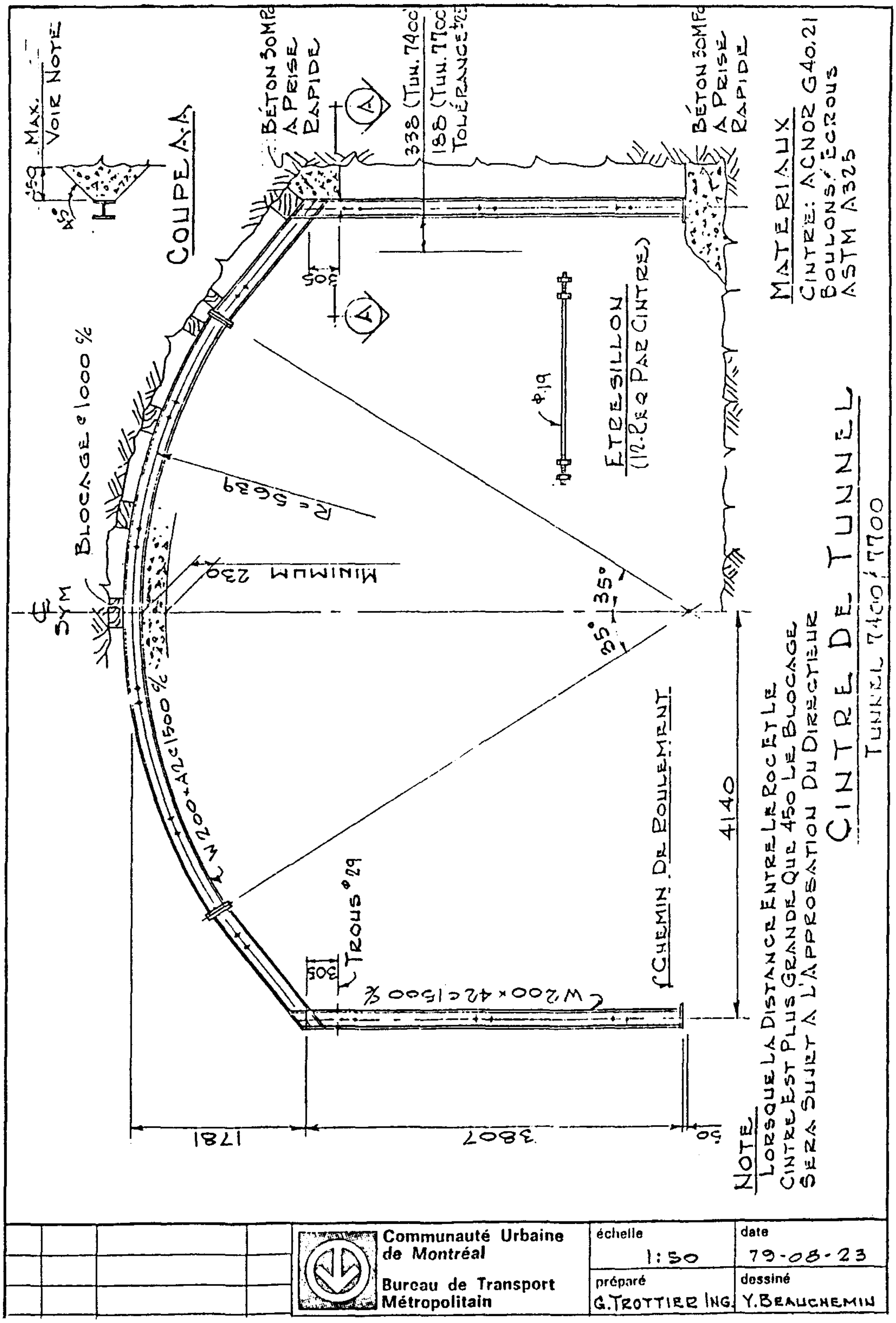
concreting tunnel



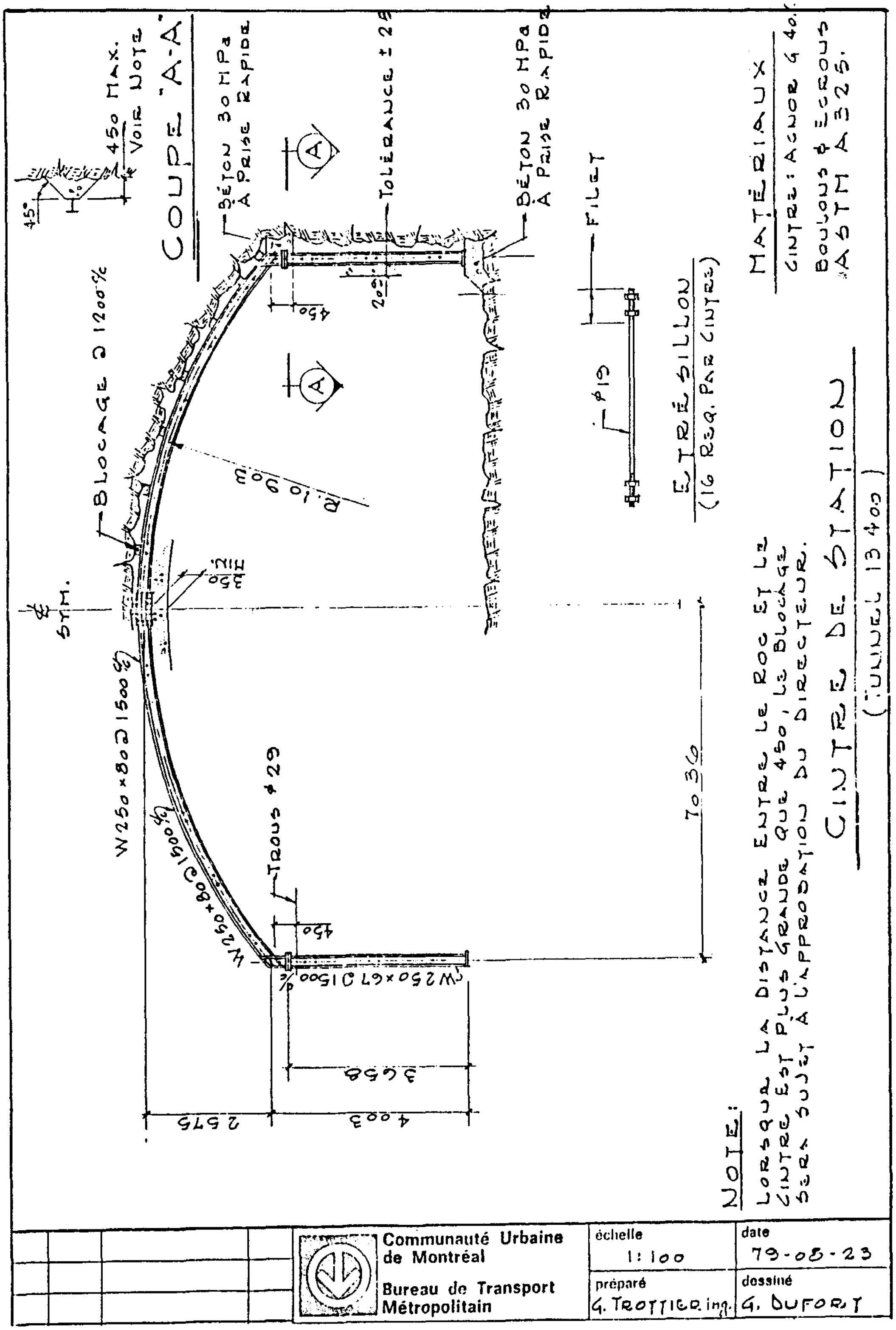
concreted tunnel

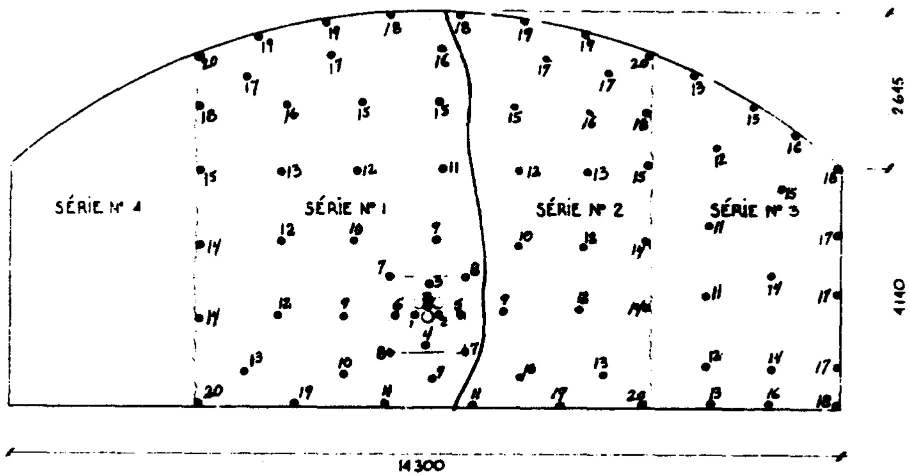


MAX. 450 | VOIR NOTE
45°
COUPE A-A
BÉTON 30 MPa À PRISE RAPIDE
A
TUNNEL 7200 TOLÉRANCE ±25
BÉTON 30 MPa À PRISE RAPIDE
MATÉRIAUX
CINTRE: ACIER G40.21
BOULONS & ECROUS: ASTM A325
305
286
FILET
BLOCAGE @1000 c/c
φ19
ETRÉSILLON
(12-REQ. PAR CINTRE)
R=5639
MINIMUM 230
SYM.
35°
35°
W 200×42@1500 c/c
TROUS φ29
CHEMIN DE ROULEMENT
3988
305
W 200×42@1500 c/c
1653
3936
50
NOTE
LORSQUE LA DISTANCE ENTRE LE ROC ET LE CINTRE EST PLUS GRANDE QUE 450 LE BLOCAGE SERA SUJET À L'APPROBATION DU DIRECTEUR.
CINTRE DE TUNNEL
TUNNEL 7200
Communauté Urbaine de Montréal
Bureau de Transport Métropolitain
échelle 1:50
date 79-08-23
préparé G. TROTTIER ING.
dessiné Z. JOVICIC



Sym
Blocage @ 1000 %
Max.
Voir Note
Coupe A-A
1781
3807
50
4140
W200×42 @ 1500 %
Minimum 230
R = 5639
305
Trous Ø 29
35°
35°
Béton 30 MPa
À prise rapide
338 (Tun. 7400)
188 (Tun. 7700)
Tolérance ±25
Ø 19
Etresillon
(12 req. par cintre)
Chemin de roulement
Note
Lorsque la distance entre le roc et le cintre est plus grande que 450 le blocage sera sujet à l'approbation du directeur
Cintre de Tunnel
Tunnel 7400 / 7700
Matériaux
Cintre: ACNOR G40.21
Boulons / Écrous ASTM A325
Communauté Urbaine de Montréal
Bureau de Transport Métropolitain
échelle
1:50
date
79-08-23
préparé
G. Trottier Ing.
dessiné
Y. Beauchemin


℄ SYM.
BLOCAGE @ 1200 c/c
W250×80 @ 1500 c/c
W250×80 @ 1500 c/c
W250×67 @ 1500 c/c
TROUS ø 29
450
450
2575
4003
3658
7036
350 MIN.
R. 10 903
20
TOLÉRANCE ± 25
BÉTON 30 MPa À PRISE RAPIDE
BÉTON 30 MPa À PRISE RAPIDE
45°
450 MAX. VOIR NOTE
COUPE "A-A"
A
A
ø19
FILET
ETRÉSILLON
(16 REQ. PAR CINTRE)
NOTE:
LORSQUE LA DISTANCE ENTRE LE ROC ET LE CINTRE EST PLUS GRANDE QUE 450, LE BLOCAGE SERA SUJET À L'APPROBATION DU DIRECTEUR.
CINTRE DE STATION
(TUNNEL 13 400)
MATÉRIAUX
CINTRE: ACNOR G 40.
BOULONS & ECROUS ASTM A325.
Communauté Urbaine de Montréal
Bureau de Transport Métropolitain
échelle
1:100
date
79-08-23
préparé
G. TROTTIER ing.
dessiné
G. DUFORT



A) PERCÉE CENTRALE - SÉRIES 1 & 2 -

FORAGE : 62 TROUS DE 45 x 4650
3 TROUS DE 75 x 4650

EXPLOSIFS : CILGEL B 60 kg
ANFO 190 kg
X ACTEX 12 kg
Poids total 262 kg

AMORCES : TYPE : MACRO-RETARD ÉLECTRIQUE
PÉRIODES : 0 @ 20

POIDS MAXIMUM D'EXPLOSIF PAR PÉRIODE : 3 TROUS x 4.56 kg/trou = 13.68 kg

B) ÉLARGISSEMENT - SÉRIES 3 & 4 -

FORAGE : 17 TROUS DE 45 x 4650

EXPLOSIFS : CILGEL B 25 kg
ANFO 50 kg
X ACTEX 3 kg
Poids total 78 kg

AMORCES : TYPE : MACRO-RETARD ÉLECTRIQUE
PÉRIODES : 11 @ 18

POIDS MAXIMUM D'EXPLOSIF PAR PÉRIODE : 3 TROUS x 4.56 kg/trou = 13.68 kg

NOTE

1- CHACUNE DES SÉRIES SONT DÉPHASÉES DE 100 MILLISECONDES
2- LA PERCÉE CENTRALE DEVANCE L'ÉLARGISSEMENT DE 12 MÈTRES

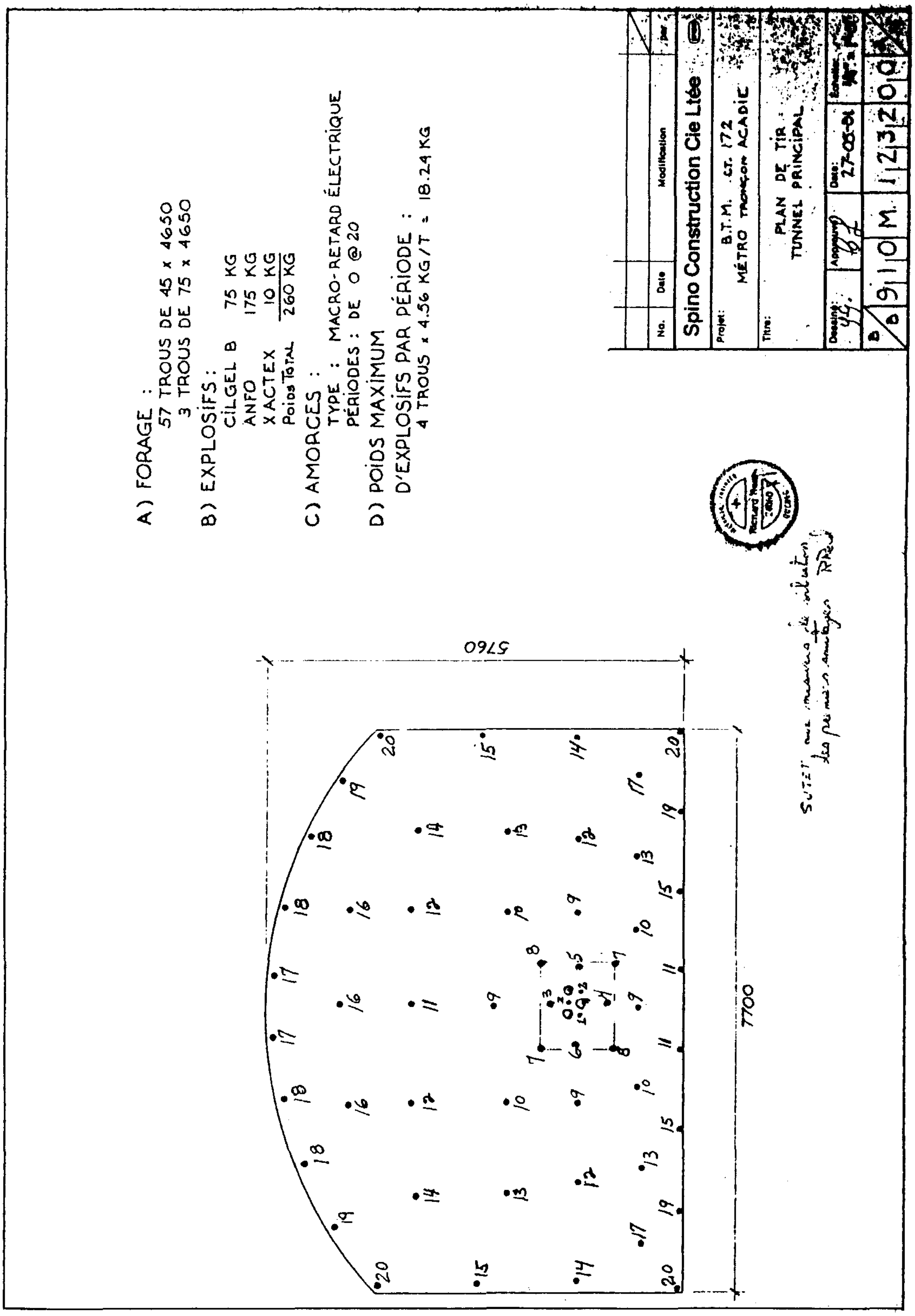
Spino Construction Cie Ltée

Projet: B.T.M. ct. 172 MÉTRO TRONÇON ACADIE

Titre: PLAN DE TIR STATION

Échelle: 1:50

C/C 910 M 123600


A) FORAGE :
57 TROUS DE 45 x 4650
3 TROUS DE 75 x 4650
B) EXPLOSIFS :
CILGEL B 75 KG
ANFO 175 KG
XACTEX 10 KG
Poids Total 260 KG
C) AMORCES :
TYPE : MACRO-RETARD ÉLECTRIQUE
PÉRIODES : DE O @ 20
D) POIDS MAXIMUM
D'EXPLOSIFS PAR PÉRIODE :
4 TROUS x 4.56 KG/T = 18.24 KG
5760
7700
No.
Date
Modification
Spino Construction Cie Ltée
Projet:
B.T.M. CT. 172
MÉTRO TRONÇON ACADIE
Titre:
PLAN DE TIR :
TUNNEL PRINCIPAL
Dessiné:
Approuvé:
Date:
27-05-01
9110M.123200