A History of Shotcrete Use at Vale Inco

By John Larsen, Denis Thibodeau, and Joe Hutter

Vale Inco mining company is a leading producer of nickel, copper, cobalt, and precious metals and has been operating in Sudbury, ON, Canada, located about 240 miles (400 km) north of Toronto, for more than 100 years. The company's Sudbury operations form the largest fully integrated base metals mining complex in the world, consisting of five operating underground mines, mill, smelter, and refining plants to produce 149,000 tons (135,000 tonnes) of finished nickel metal and powder per year.

Shotcrete at Vale Inco—The Early Years

Vale Inco first began to use a form of shotcrete in the early 1970s. A thin layer of sprayed mortar (generally referred to as gunite) was applied, using the dry-mix process, as a water sealant for garages, shaft stations, and lunchrooms. The material was sprayed over bolt and screen and, in many cases, was subsequently painted to provide improved lighting for the workers. The material was not suitable for use in operating headings—with blasting effects—because the mortar layer would split, crack, and spall under intense dynamic loading conditions (Fig. 1). In these early years, the sprayed mortar was trialed in a ground support application at several Inco mines where ground conditions were extremely poor. The mortar was unsuccessful at providing support because it was applied too thin, too late after the ground "relaxed," and its compressive and flexural strengths were inconsistent and weak (Espley et al. 2001).

Fig. 1: First shotcrete attempt with cement, sand, and water mixture (mortar-like) showing poor performance with cracking

During the early 1980s, shotcrete manufacturers began to pay more attention to mixture designs in an effort to improve both the plastic and hardened properties of the shotcrete mixtures. More effective aggregate gradations (adding coarse aggregates) improved strength and shootability, the use of pozzolans such as silica fume allowed for thicker passes per application, the addition of noncaustic accelerators reduced set times and increased the rate of strength gain, and steel fibers were added to increase energy absorption capacity and improve toughness and post-cracking strength.

Shotcrete for Underground Construction

Before shotcrete was adopted extensively within the Vale Inco mines as a product for ground support, it saw wide use as a replacement for conventionally placed concrete in non-civil engineered underground construction. The challenges faced when handling and placing ready mixed concrete underground were significant. Ready mixed concrete delivered to the shaft head frame was dumped into steel boxes of 1 to 3 yd^3 (0.8 to 2.3 m^3) capacity. The steel boxes would travel via the shaft to the underground levels and then be handled by equipment designed primarily for mine production activities to distant and remote locations. Placement of the concrete into crude forms was difficult and often done by hand (using pails). The cycle time from delivery to the shaft collar on surface to the pour site (after multiple handling situations) could be 2 to 4 hours. Set retardants and other chemicals to modify hydration were not often used and quantities of concrete would be lost.

On the other hand, bagged dry-mix shotcrete provided an excellent solution to the handling problems. Bagged material on pallets could be handled by a variety of equipment and transported to construction sites by underground mine boom trucks. One-sided forms for construction were easier to build and contained a designed cage of reinforcing bar if required. Sprayed concrete was vastly superior to dumping conventional concrete into forms and overall construction times were reduced. For installations such as ore pass mantles, ventilation control walls, and minor dams, as well as for concrete repairs, dry bagged shotcrete provided a quick, simple, and cost-effective means for concrete construction in the underground environment.

Shotcrete as a Ground Support Tool

Vale Inco's first use of shotcrete as a ground support tool occurred in the very early 1980s at the company's Creighton Mine near Sudbury, ON, Canada. Shotcrete was used to supplement bolt and screen in high-stress conditions in a raise (Fig. 2). Since this time, the use of shotcrete at Vale Inco mines has increased, initially with site-specific applications and then, over time, with more mine-wide applications.

By the late 1980s, new and improved shotcrete materials were being used underground in the Vale Inco mines, initially as a structural support element (for construction) and for ground support in major underground excavations such as hoist rooms, garages, and crusher stations. Shotcrete was chosen for these applications when the cost of the product and installation seemed warranted. In many cases, the shotcrete that was used in permanent excavations was applied over existing support. The base support was usually quite extensive, with such items as cable bolts, screen, and grouted reinforcing bar bolts. Shotcrete improved stability of the entire support system. It was, however, very costly. At the time, shotcrete use was infrequent and its relatively low demand within the industry resulted in having its application contracted out—usually at high cost. The low-demand and high-cost factors obviously slowed the integration of shotcrete into the mining operations and, in particular, into the mining cycle.

Problems associated with material handling and shotcrete equipment also slowed the integration of shotcrete into existing mining operations. In fact, in most cases, the shotcrete equipment used in Vale Inco mines had undergone little change in several decades. Machines produced large amounts of dust; were expensive to operate; and involved labor intensive, hand-held nozzeling techniques. Materials were generally supplied in small, 66 lb (30 kg) bags, which when broken into hoppers, creating unacceptable dust levels. All of these factors led to the opinion that shotcrete was a costly, laborious, and slow method of ground support applicable only to permanent or special excavations and was not suitable as a routine method of ground support.

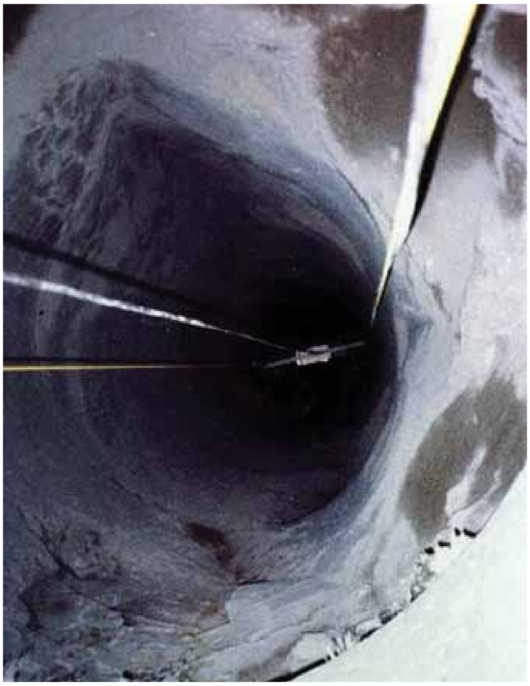

Fig. 2: Shotcrete use in raise

Fig. 3: Large, 2200 lb (1000 kg) bulk bags that allowed more material to be moved more quickly throughout the mine

In retrospect, it is now clear that the late 1980s signaled the turning point for shotcrete whereby a new credibility was growing for the product and for its emerging role as a key ground support tool, not only at Vale Inco but also throughout the mining industry. Equipment improvements and improvements in material handling contributed to the increased popularity of shotcrete at Vale Inco mines. The small paper bags were replaced by large 2200 lb (1000 kg) bulk bags that allowed more material to be moved more quickly throughout the mine (Fig. 3). New, more rugged shotcrete machines, designed to contain dust, were supplied

Fig. 4: Shotcrete sprayers increased the comfort level of the nozzelman, improved productivity, and created a safer work environment

Fig. 5: Corroded screen and bolts

Fig. 6: Blast damage in topsill

with hopper hoods that reduced dust levels and protected the arms of workers. The shotcrete nozzle, redesigned to reduce dust levels, was taken out of the hands of the nozzelman and placed at the end of remote booms. These "shotcrete sprayers" increased the comfort levels of the

Fig. 7: Rock burst

nozzelman, improved productivity, and created a safer work environment (Fig. 4).

During the late 1980s, it became apparent that there were three key roles for which shotcrete could be used to supplement bolt and screen:

1. For protection of the existing support from corrosion or from fly-rock damage due to blasting, for example, secondary-blasting chambers and top sills for vertical retreat mining (VRM) (Fig. 5 and 6);
2. For enhanced support in seismically actives zones, for example, rib pillars, crusher stations, headings at depth, and crown pillar regions (Fig. 7); and
3. For reconditioning or for mining in difficult ground conditions, for example, when mining through backfill, crushed zones, or through geological structures; severely relaxed ground; large intersections; draw-points; or large permanent openings. For all scenarios, the shotcrete application at Inco was typically applied at a thickness of 2 to 4 in. (50 to 100 mm). The excavation was usually completely mined and supported with the primary ground support and then the shotcrete was applied in one main process.

Shotcrete Use at Vale Inco's Frood Mine

By the late 1980s, a dry-mix shotcrete product was used for the first time at Vale Inco's Frood Mine, Sudbury, ON, Canada, to support and recondition heavily deteriorated ground on the 1000 Level gangways. In these areas, corroded bolt and screen and rotted timbers made for a challenging ground support strategy. Ultimately, shotcrete was considered a safer alternative to bolt and screen. The dry-mix shotcrete, supplied first in bulk bags, and later through a bulk carrier with a shotcrete machine mounted at the back, was sprayed over the existing bolt and screen to form an arched support. These conditions made it difficult to achieve a compacted, thick layer of shotcrete and, as a result, many voids were created behind the screen.

Even though the shotcrete application was far from optimum, it performed better than expected by controlling further deterioration of the rock mass and tying the loose rock together at the excavation surface. Because the results were good, the mine outlined several other areas that needed to be reconditioned with shotcrete.

One of the greatest challenges faced by the Frood Mine management was convincing the underground miners that what appeared to be a relatively thin layer of sprayed concrete would be able to support the thousands of tons of loose and fractured rock that remained overhead. Many looked at shotcrete as "hiding potential problem areas," most of which could be monitored by observing "loose," or chunks of fallen rock, that was found hanging in the overhead screen. Using case histories and scientific data, shotcrete material manufacturers conducted seminars that explained the theory of how shotcrete stabilized a rock mass and actually helped identify problem areas by identifying visible cracks in the shotcrete, many which formed when there was significant ground movement.

Frood Mine's first shotcrete-dedicated crew (most shotcrete personnel had other responsibilities among which shotcrete was included) was formed and trained in 1988 when Frood Mine purchased its first dry-mix machine. Shotcrete use grew beyond reconditioning during 1989 and 1990 to include construction of dump walls, ventilation barricades, backfill barricades, and ore pass mantles.

In 1990, Frood Mine tested mesh-reinforced shotcrete as primary ground support in some production headings on 1170 Level—mostly in late-stage pillar recovery zones with sand slots located above the headings (Fig. 8). The shotcrete was needed to provide stability in the crushed ground conditions and to control large deformations. In loose rubble conditions, it was extremely difficult to install bolt and screen. The mine developed the following shotcreting procedure for each 12 ft (3.6 m) development round:

1. Spray plain shotcrete 2 to 4 in. (50 to 100 mm) thick on the back and walls;
2. Allow shotcrete to cure for a minimum of 8 hours;
3. Attach screen to the shotcrete with bolts; and
4. Spray a second layer of plain shotcrete 2 to 4 in. (50 to 100 mm) thick over the screen.

Experience at Vale Inco's Stobie Mine—"Boltless Shotcrete"

Shotcrete was first used at Vale Inco's Stobie Mine, Sudbury, ON, Canada, in sublevel cave mining areas to provide corrosion protection to bolt and screen in the drill drifts and to provide additional support to the brows during production mining. By 1993, problems associated with drilling led mining engineers to consider using shotcrete as a replacement for bolt and screen in the sublevel cave production headings. This change was prompted by the following:

1. Constant complaints of stuck rods with the top-hammer drills and with excessive wear of the bits (due to drilling into the back bolts);
2. The support capacity of a bolt being compromised when the production drill would hit and damage the bolt's steel shaft; and
3. Difficulty with loading the drilled production holes with emulsion explosives due to deterioration of the ground around the collars, as well as the loading process becoming quite dangerous.

A trial in which boltless shotcrete would replace conventional ground support provided Vale Inco engineers with an opportunity to test the limits of a ground support system in which shotcrete played a primary role and bolts were eliminated (Espley et al. 1994).

The trial was performed in three distinct phases:

Phase 1: In 1993 and 1994, a two-pass, boltless-mesh reinforced shotcrete system was tested on the 2400 Level in a number of drill drifts in which remnant pillar mining was taking place. The mesh-reinforced shotcrete performed well under production and blasting conditions and provided an important support role even with tensile cracking and rock fracturing "onion skinning" behind the shotcrete liner. From the results, it was apparent that some reinforcement of the shotcrete was required to provide effective support in areas of moderate to high deformations and dynamic loading.

Phase 2: In 1994, consideration was given to replacing the mesh with steel fiber in an effort to improve development rates through the implementation of a single pass system. An underground trial was started on 1850 Level and 1930 Level, where several hundred feet of standard bolt and

Fig. 8: Frood Mine development heading

screen were removed and replaced with boltless steel fiber-reinforced shotcrete (Espley et al. 1996). These shotcreted drifts became production headings for the sublevel cave mining. The monitoring of these drifts during the production phase showed that the necessity to rehabilitate the brows was significantly reduced when compared to conventionally supported headings (screen and bolts). It was also determined that +3 in. (+75 mm) of shotcrete was required to provide effective support during production mining.

Phase 3: In 1995, the success of the second phase led to the evaluation of the support effectiveness of boltless fiber-reinforced shotcrete when applied during the development phase and used throughout the entire production phase. A boltless-steel fiber-reinforced shotcrete liner was designed using site data, empirical data, laboratory information, and through experience with shotcrete in civil and mining operations (Espley 1996).

Fig. 9: Application of boltless SFRS

Fig. 10: Sublevel drill drift supported with boltless SFRS

Fig. 11: Brow of mucking drift with boltless SFRS

In 1995, the drill drifts on 2000 Level were sprayed with steel fiber-reinforced shotcrete (SFRS) as part of the development mining cycle as follows: 1) drill, load, blast, and muck the heading; 2) scale using an air/water spray; 3) apply 4 in. (100 mm) of SFRS to the back and walls (at a dosage rate of 100 lb/yd^3 [60 kg/m^3]). After a cure time of 12 hours, personnel were permitted to reenter the heading. Field observations and performance evaluation during these trials led to the conclusion that the support system worked quite well for back support. It was also determined that boltless shotcrete greatly improved the collaring, drilling, and loading of production holes as shown in Fig. 9 to 11.

The support design has since been expanded to all sublevel cave development headings with good to very good ground conditions and low to moderate stress levels. It was also determined that all drift intersections be supplemented with grouted reinforcing bar bolts on a 4 ft (1.2 m) square pattern. From the standpoint of shotcrete materials, improvements in shotcrete mixture design led to an improvement in process cycle time whereby the 12-hour reentry time was reduced to 8 hours. It was also determined through testing that the specified steel fiber dosage could be reduced from 100 to 84 lb/yd^3 (60 to 50 kg/m^3).

Shotcrete Use Expands to Other Vale Inco Properties

The experience gained from Frood and Stobie Mines and the initial proof of shotcrete's ability to support rock in challenging ground conditions, led to the logical progression to question if shotcrete would be able to withstand high vibration from production blasting. To answer this question, trials were undertaken to test the effectiveness of shotcrete under these conditions. Each trial was site-specific, with an emphasis on monitoring the support performance both during development and during production phases of mining. Additionally, all other operational aspects and costs for each trial were tracked and used in a post-trial assessment.

In 1991, Vale Inco selected Copper Cliff North Mine, Copper Cliff, ON, Canada, near Sudbury, to conduct the next phase of shotcrete testing in which shotcrete would be used as a secondary support for bolt and screen (O'Donnell 1991). The shotcrete was used in a VRM top sill to protect the steel support elements from the fly-rock ejected during production blasts. This trial was extremely successful and, as a result, most Inco mines now use shotcrete as secondary support in the VRM sills (Fig. 12). In the top sills, shotcrete controls damage of support from blasting. In bottom sills, the shotcrete is sprayed over bolt and screen to improve brow conditions and to eliminate the need for cable bolts. Since the introduction of this application, the added shotcrete layer has eliminated a large amount of reconditioning of bolt and screen (and cable bolting in brows) in the sills.

In 1992, Vale Inco began to use shotcrete in earnest in various other operations. One of the first and very successful trials was to test shotcrete for the replacement of steel and timber sets (Fig. 13). This was first examined at Frood Mine as a replacement of the sets and later shotcrete was trialed at Creighton Mine, near Sudbury, ON, Canada, in the production sills, as a replacement to its timber sets. This worked well where deformations were not excessive (Fig. 14).

Another important application for shotcrete at Creighton Mine was to provide support when mining through backfill. In this application, 6 ft (1.8 m) rounds were developed and supported with layered elements: 1) the first layer of plain (unreinforced) shotcrete, approximately 2 to 4 in. (50 to 100 mm) thick, was applied and cured for a minimum of 8 hours; 2) screen was pinned to the back and walls with short friction bolts; and 3) the second layer of plain shotcrete, approximately 2 to 4 in. (50 to 100 mm) thick, was applied to cover the screen.

At Creighton Mine deep (7800 ft level [2377 m]), consideration must be given to the moderate- to high-stress environments encountered when mining at these depths. The shotcrete must have energy absorption (that is, dynamic) capacity to survive potential bursting conditions. As such, laboratory or observational data were required for an estimate of the dynamic capacity of the shotcrete systems to compare to the estimated dynamic loads. When evaluating the effectiveness of shotcrete under the conditions at Creighton Mine and other Vale Inco mines, it was determined that infrastructure damage (caused by seismic activity) was reduced considerably when shotcrete was integrated into the support system (Fig. 15).

The Increased Use of Shotcrete as a Construction Tool

Through the 1990s, there was an increasing familiarity and use of dry-bagged shotcrete as a ground support tool in the underground mining environment at Vale Inco. This familiarity and the increasing availability of shotcrete underground resulted in the increased use of shotcrete as a construction material. Strength testing through the extraction of cores and stringent quality-control programs incorporated by shotcrete material suppliers provided Vale Inco engineers with the confidence that shotcrete would provide the

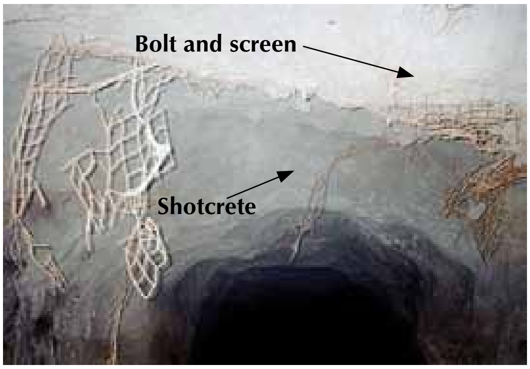

Fig. 12: Shotcrete use in VRM topsill

Fig. 13: Timber sets at Creighton Mine

Fig. 14: Shotcrete use to replace timber sets

Fig. 15: Shotcreted drift at Creighton Mine (after seismic activity)

consistent in-place properties required to incorporate shotcrete process into the construction design process. Critical applications such as the construction of arched backfill barricades are now designed using shotcrete, allowing the elimination of expensive timber as the fill barricade material and creating a much less labor-intensive construction process. Performances of the barricades are also vastly improved.

Placed concrete has been virtually eliminated as the construction material in non-load and low load-bearing walls and low head dams for ventilation control, installation of fans, sumps, and material storage bunks. Nonaccelerated shotcrete is used for low load-bearing floors in permanent installations such as refuge stations, materials storages, and shaft stations. In permanent, long-term installations where replacement and reconditioning of steel bolt and wire mesh ground support would prove disruptive to the operation, shotcrete is used exclusively to seal and protect the ground support. This includes:

- underground garages;
- electrical, shaft, crusher, and fan stations;
- bins;
- conveyor galleries;
- equipment and material storages; and
- powder and fuse magazines.

New high-performance shotcrete mixtures, developed by shotcrete materials manufacturers to protect and extend the life of ore bins, are now replacing steel plate liners. These mixtures use high-performance, aluminate-based cements that improve abrasion resistance and allow ore bins to be reopened days after the application of the shotcrete. Steel fibers protect the liner against impact and provide improved energy absorption.

Fig. 16: Wet-mix shotcrete material is delivered from a bore hole on surface and dropped several thousand feet (meters)

These mixtures are now being used in high impact areas such as draw points, truck dumps, around grizzlies, surface bins, ore passes, and other areas subjected to high impact and high abrasion. Vale Inco's Coleman Mine, Levack, ON, Canada, located 31 miles (50 km) north of Sudbury, has monitored the performance of these calcium aluminate cement (CAC)-based mixtures in ore passes by lowering video cameras into the ore pass and examining the condition of the shotcrete liner. The results have prompted Vale Inco engineers to specify more CAC, steel fiber-reinforced mixtures in high impact areas at other Vale Inco properties.

Wet-Mix Shotcrete at Vale Inco

The use of wet-mix shotcrete at Vale Inco has been limited to the extensive application at Frood and Stobie mines as a principal part of the ground support at each site. As a result, shotcrete volumes at these two adjoining operations are sufficient to justify the capital expense of surface to underground boreholes to deliver wet-mix shotcrete underground at the sites and mobile equipment for application. As volumes have increased, typically beyond 7848 to 10,464 yd^3 (6000 to 8000 m^3) per year, other Vale Inco mines (Coleman, Garson) have instituted plans to implement a wet shotcrete system.

The primary advantages of wet-mix shotcrete are the improvements in materials handling and increases in productivity. At Vale Inco, current procedures require material delivery (via conventional ready mixed truck) to a bore hole on the surface from where it is dropped several thousands of feet (meters) and received in a bulk carrier at specified production levels (Fig. 16). The bulk carriers are used to transport the shotcrete throughout the mine to development headings where shotcrete sprayers (with a concrete pump, accelerator dosing units, and remote spray arms) apply shotcrete at much increased rates of application. These productivity improvements have allowed Frood and Stobie Mines to expand the use of shotcrete and investigate the support systems that include boltless, steel fiber-reinforced shotcrete liners.

Health and safety issues are also at the forefront when evaluating the benefit of a wet-mix shotcrete program. Dust levels become less of a factor during the shooting process. Reduced manual handling and reduced time exposure for comparable amounts of shotcrete applied also play a role in improving the health and safety conditions underground.

The Future of Shotcrete at Vale Inco

The growth of shotcrete use at Vale Inco has been expeditious since the days when underground miners were uncomfortable with its use as a ground control tool. Properties (both plastic and hardened) achieved using early mixture designs were inadequate; therefore, shotcrete was limited to nonstructural construction applications or as a secondary form of ground support. Today, however, shotcrete mixture designs have undergone exceptional improvements. Improved hardened properties have allowed engineers to incorporate the shotcrete process into the design of structural elements, equipment improvements have led to reduced dust levels, steel and macro-synthetic fibers have improved the ability of shotcrete to absorb energy, and the use crews dedicated to shotcrete have resulted in improved nozzelman skills and, in turn, more consistent, high-quality shotcrete applications.

In the future, shotcrete use at Vale Inco is expected to increase as the commercial benefits of shotcrete support systems become more apparent. The need to bring ore bodies on line quicker will contribute to production improvements. Shotcrete will be used as primary support in narrow vein mines and wide cut-and-fill headings. Improved early-age strength testing procedures will allow reductions in reentry time. Increased use of fibers will reduce the need for wire mesh and speed up the development cycle. Automation of the shotcrete process will also contribute to a faster mining cycle.

Vale Inco mines will also benefit from improvements in material handling. Wet-mix shotcrete will play a bigger role in ground support strategies as mixtures are delivered via bore hole and larger volumes are transported in bulk carriers. "Dry to wet" systems will be developed, allowing preblended dry materials to be delivered either in bags or in bulk (also through bore holes) to mixing stations where wet-mix shotcrete can be produced on demand and without many of the costly admixtures currently used.

Perhaps one day, the shotcrete application will be automated to the point where automated bulk shotcrete carriers, controlled from the surface, can be maneuvered from the shaft station to headings several thousands of feet (meters) away. At the heading, automated shotcrete sprayers will be operated by nozzlemen remotely controlling spray arms from the surface; and shotcrete mixture designs, capable of providing higher strengths minutes after application, will improve productivity, reduce costs, and make more ore bodies commercially viable.

Whereas these concepts may seem like a long way from current mining methods, one must realize that implementation of video technology, telecommunications, modems, and PCs have allowed automated load-haul-dump vehicles to be used underground at Vale Inco's Creighton Mine since 1991. If this technology can be applied to the shotcrete process (bulk carriers and shotcrete sprayers), the concept of automated shotcrete processes may not be too far away.

References

Espley, S., 1996, "Stand-Alone Boltless Shotcrete for Stobie Mine," Internal Memorandum, Inco Limited, Mines Research, Ontario Division.

Espley, S.; Langille C.; and McCreath, D., 1994, "Innovative Liner Support Trials in Underground Hardrock Mines," CIM 96th AGM Proceedings, Toronto, ON, Canada.

Espley, S.; Malek, F.; and O'Donnell, J., 2001, "INCO's Experience with Shotcrete for Ground Support," Australian Center for Geomechanics, International Seminar on Mine Surface Support Liners 2001, Membrane, Shotcrete and Mesh, Perth, Australia, Sec. 9, pp. 1-22.

Espley, S.; O'Donnell, J. D. P.; Thibodeau, D.; and Paradis-Sokoloski, P., 1996, "Investigation into the Replacement of Conventional Support with Spray-on Liners," CIM 98th AGM Proceedings, Edmonton, AB, Canada.

O'Donnell, J. P. D. Sr., 1991, "Support for CC North Mine VRM Top Sills," Internal Document, Inco Limited, Mines Research, Ontario Division.

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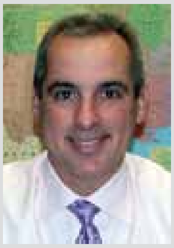

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