Digital Delay Blasting At United Taconite LLC

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Introduction

United Taconite is an iron ore mine operated by Cleveland-Cliffs Inc (Cliffs) located near Eveleth, Minnesota. The mine, originally known as Eveleth Taconite Mines, was purchased in December 2003 by Cliffs (70%) and Laiwu Steel (30%). The mine site, known as the Thunderbird Mine, produces taconite ore for delivery by rail to the company's Fairlane plant, located approximately 10 miles to the south near Forbes, Minnesota. At the plant, the crude ore is ground, concentrated and processed into pellets for steel industry customers. Total pellet production capacity is about 5.4 million long tons (Ltons) per year.

Figure 1. Minnesota Map

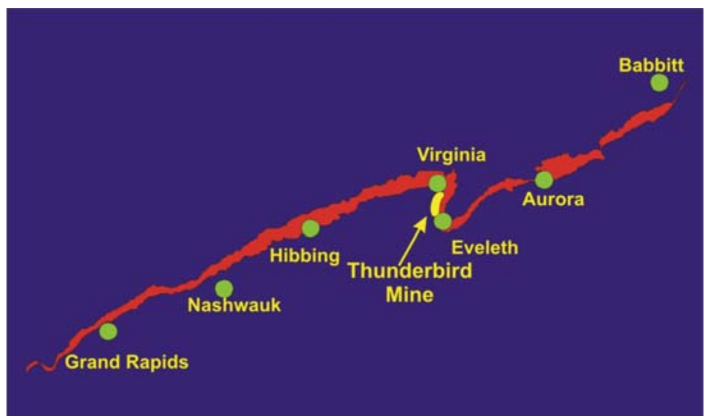

Figure 2. - Mesabi Range

In 2004, the mine began to experiment with programmable electronic detonators for improved blasting control due to the close proximity of surrounding communities. This paper is a case study involving open-pit iron ore mining. United Taconite was looking for a viable means to conduct blasting some 350 feet from a nearby four-lane highway and under 1500 feet from occupied dwellings. To put these distances into perspective, it should be noted that a normal clearing radius for equipment at other Mesabi Range mines is some 1000 feet.

Geology

The Thunderbird Mine is located in northern Minnesota approximately 65 miles north of the City of Duluth (see Fig. 1). The mine site lies on the northwest limb of the Virginia Horn, a large fold structure (see Fig. 2) in the Biwabik Iron Formation located in the approximate center of Minnesota's Mesabi Iron Range.
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The Biwabik Iron Formation is a Precambrian sequence of iron-bearing sedimentary rocks that have undergone low grade metamorphism. The formation has been divided into four major subdivisions of alternating cherty and slaty horizons. The iron-formation sediments were deposited in a shallow marine environment. The granular, cherty rocks were deposited near-shore, while the fine grained, laminated, slaty rocks formed in a deep basin environment. The formation is shallow dipping with a 110-mile exposure along the strike. The iron-formation is very hard, being composed mainly of fine grained iron silicates, presenting a challenge to rotary drilling. The mine blends three ore zones from the lower, middle and upper portions of the iron-formation.

Thunderbird Mine

The mine is a conventional, open pit mine with 35-foot level benches with inter-bedded rock and ore layers exposed as the mine progresses down dip and along the strike of the formation (see Fig. 3). As ore is mined out along the footwall, stripping stockpiles have been established on waste rock along the up-dip side of the formation.

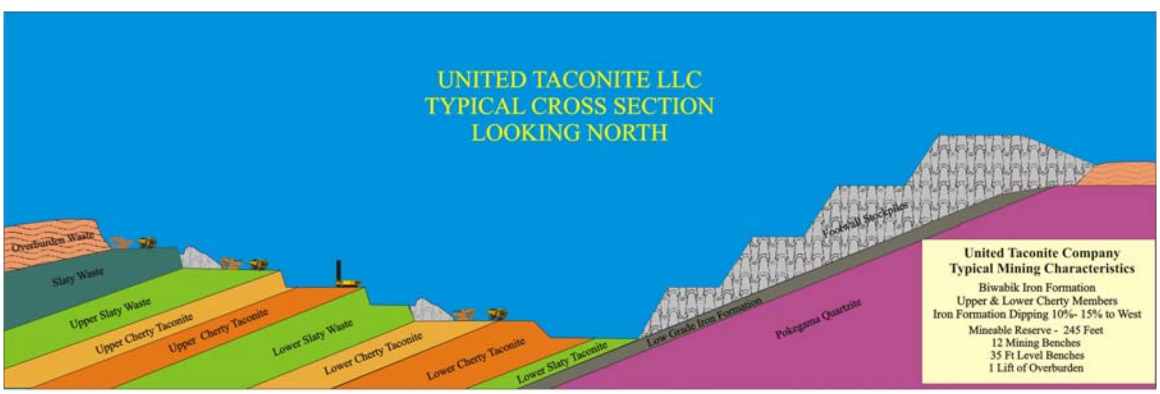

Figure 3. - Typical Cross Section

The mine operates a fleet of eleven haul trucks (190 and 240-ton), three – hydraulic shovels (23 cu. yd), two – front-end loaders (28 yd.), and three rotary drills using 16 inch bits. The 2005-scheduled production at the mine site is about 16 million Ltons of crude ore, 2.2 million Ltons of surface and 10 million Ltons of rock. This requires 26 million Ltons of blasted material during the course of the year.

The mine layout shown in Fig. 4 identifies a mix of rock and ore.

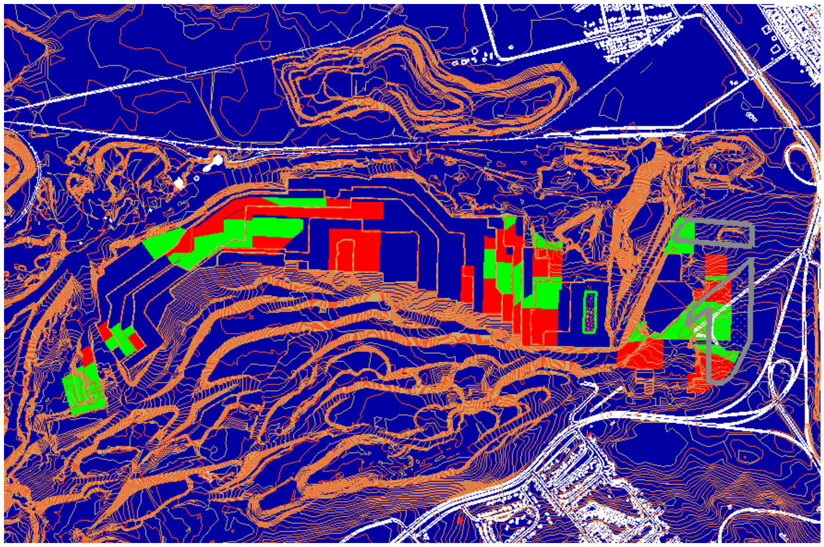

Figure 4. – Mine Layout

Approximately 50 percent of the blast patterns are perpendicular to the strike of the formation resulting in a mix of ore and waste. The red zones represent blocks of ore with the green zones representing rock stripping. The diagram also serves to show the close proximity of the surrounding communities of Virginia and Eveleth. Some of the blasting is within 1,000 feet of local residential housing and within 500 feet of a major State highway. Due to the close proximity of these local communities, the blasting activity at the Thunderbird requires careful control. Improvements were sought over the pyrotechnic based delays ability to provide the needed accuracy and fragmentation. The mine required a means to accurately control its blasting with a product robust enough to withstand the mine's harsh environment. The mine chose to accomplish this task through the use of Orica's down-the-hole i-kon™ electronic detonators.

Initial Test

The initial testing began in October, 2004. This phase of testing culminated with a blast located within 1,200 feet of a residential area and 300 feet from the highway. The pattern was designed with a 21-foot square burden and spacing and drilled with a 12¼-inch rotary bit to reduce the maximum pounds of powder per delay. Later patterns were drill with 16-inch rotary bits and staggered burden and spacing.

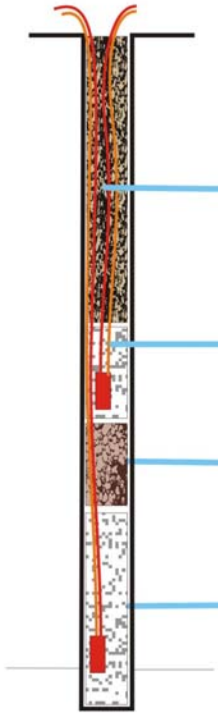

Figure 5. – Typical Deck Load

The holes were loaded with a lower and upper powder column separated by an 8-foot deck to minimize the maximum pounds per delay (see Fig. 5). Each powder column contained a two pound booster with one electronic delay and a pyrotechnic-based delay as backup. A 5 millisecond (MS) delay was used between the decks. The large stemming used at the mine damaged the down-lines of the electronic delays causing current leakage. Of the 219 detonators in the pattern, 12 electronics did not report, and the pyrotechnic backups had to be used in those holes. Although these problems resulted in a 2-hour delay in the detonation, the resulting blast was one of the most controlled blasts the mine had ever seen. With a powder factor of 0.82, ground vibration was minimal at 0.38 inches per second and there was no fly rock at detonation. With such positive results the mine felt confident in the application, but the robustness of the down-lines had to be resolved. A heavier down-line was used in subsequent electronic detonator blasts at the mine, significantly reducing, although not eliminating the number of damaged down-lines.

Even after switching to more robust down-lines, current leakage continued due to our loading practices and stemming size. In the early testing phase, the mine's +3-inch nominal stemming size and 16-inch diameter blast holes very likely damaged more than one digital delay. Those holes relied on the backup pyrotechnic delays. During stemming, the holes are filled by a front-end loader and the down-lines are unattended. Current leakage continued to be a significant problem until the mine reduced the size of the stemming to +1.25-inch nominal size late in 2005.

Acceptance of this new blasting technique didn't come without a few hurdles. With any new technology, acceptance by the blasters was not universal. Due to past experiences on the Iron Range, the blasters did not trust the electrical nature of this product nor the programming phase. Even today, after several in-house training sessions and excellent product support there is not 100 percent acceptance. The unplanned detonation of an electronic delay this past summer at a surface coal mine in Indiana added to concerns about the technology. It will take time and usage of this new technology before the blast crew safety concerns diminish.

The electronic delays allowed the mine to accurately control the detonation of individual blast holes. Achievements included: precise deck timing, multiple initiation points within a single blast, multiple close proximity blasts, elimination of cutoff concerns and material separation within a blast.

<u>Separation of Ore and Waste</u>

Due to the layout of many of the mine blasts, there is a geologic mix of ore and waste. In the conventional method of classification, a vertical line in the bank would divide the ore/waste zone (see Fig.6). The material immediately to the right of the line will be diluted ore. To the left of the line a portion of the ore will be lost to stripping.

Figure 6. - Typical Cross-Section

Electronic delays have allowed the mine to throw a wedge of waste off the ore (see Fig. 7). This is accomplished by establishing a deck load within the transition zone to follow the ore/waste contact.

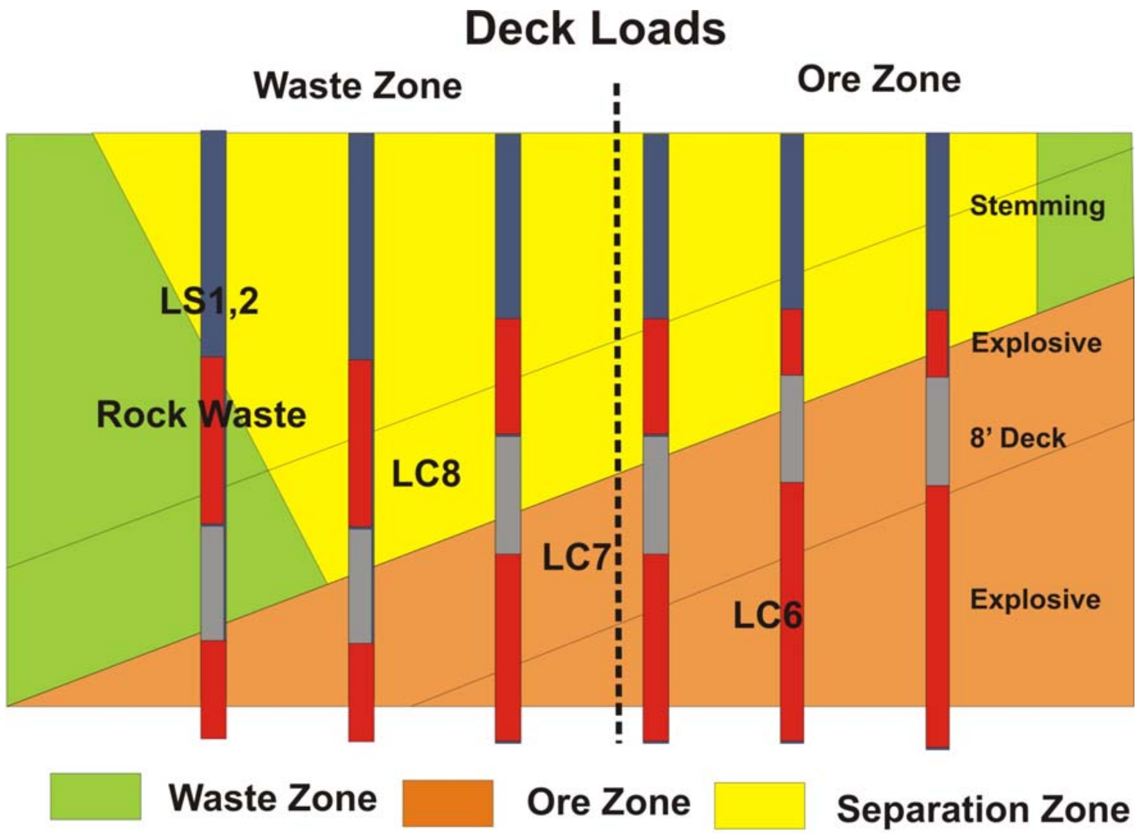

Figure 7. - Deck Load

The geology within this zone is a transition from massive cherty ore to a soft slaty waste. An eight-foot deck is used between the upper and lower loads. Drill spacing in this zone is designed with a burden and spacing of (23 feet x 27 feet) or (21 feet x 25 feet) and 5-foot sub-drill. To date the mine has completed 8 separation blasts, refining the procedures with each blast. The technique produces a depression in the muck pile, easily identified in the field.

Blast 1260-0503 was the mine’s initial separation (see Fig. 8).

Figure 8. - First Separation

Blast 1225-0508 produced the mine’s most pronounced separation (see Fig. 9).

Figure 9. - Best Separation

The equipment operators can readily identify the separation, which reduces ore delivery mistakes, increasing the amount of available ore within the blast and improving the grade of the ore in the transition zone. Through separation blasting, the mine has increased the amount of available ore tons by 4% to 8%. Within the separation zone, the grade of ore has been improved in quality. Two examples are shown in Fig. 10.

Separation Benefits

- Percentage Increase in Ore Tonnage – 4% to 8%
- Improved Ore Quality Examples:

Blast		Mag_Fe	Silica	Wtrec	CO2
1435_0506	After Separation	20.8	7.6	33.0	3.4
	Before	16.9	7.4	26.7	3.5
1225_0508	After Separation	20.8	6.4	32.3	2.2
	Before	12.8	8.3	20.2	2.6

Figure 10. – Separation Benefits

Within the separation zone, the blast holes are loaded with a variable load both top and bottom to follow the ore/waste contact. A minimum 8-foot deck separates the two loads. The top stemming will vary from 17 to 23 feet.

In plan view the separation zone is divided into three special loading zones as shown in Fig. 11. For simplicity, the zones are labeled as yellow, red, and blue with a corresponding loading chart using the same color-coding. The blasters then label the individual rotary holes in the field to simplify the pattern loading.

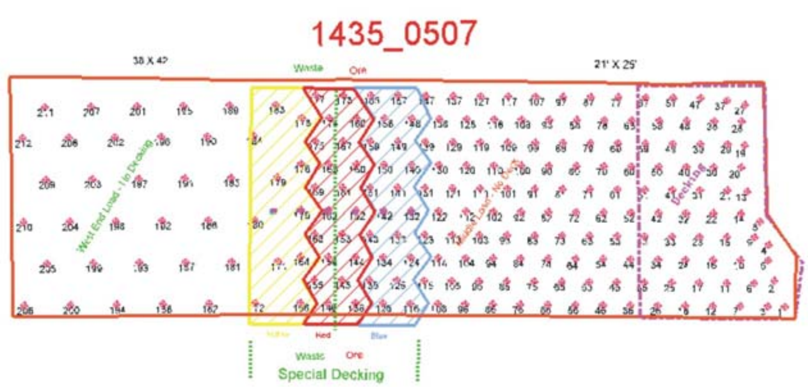

Figure 11. - Blast 1435_0507 Separation

Within the same blast pattern, another decking zone can be seen. This zone was established to reduce the pounds per delay because of close proximity to the neighboring community to the east. During initiation, the top and bottom loads in this zone will be detonated with a 5 MS delay, while the separation zone has variable timing.

On blast day, the individual electronic delays are programmed into loggers that contact the pre-engineered pattern delays. A minimum of 4 loggers are used per pattern. The loggers are connected into a blasting machine in a close proximity blasting shelter. A typical pattern will contain approximately 500,000 Ltons of material, with about 250 blast holes. Within the same pattern, the burden and spacing will vary depending on the ore-rock classification. A 23-foot x 27-foot burden and spacing is normally used in ore, with a 38-foot x 42-foot burden and spacing used in waste. When this phase has been completed the blast pattern is cleared for safety, in preparation for remote detonation. In separation blasting, the patterns are initiated from two directions.

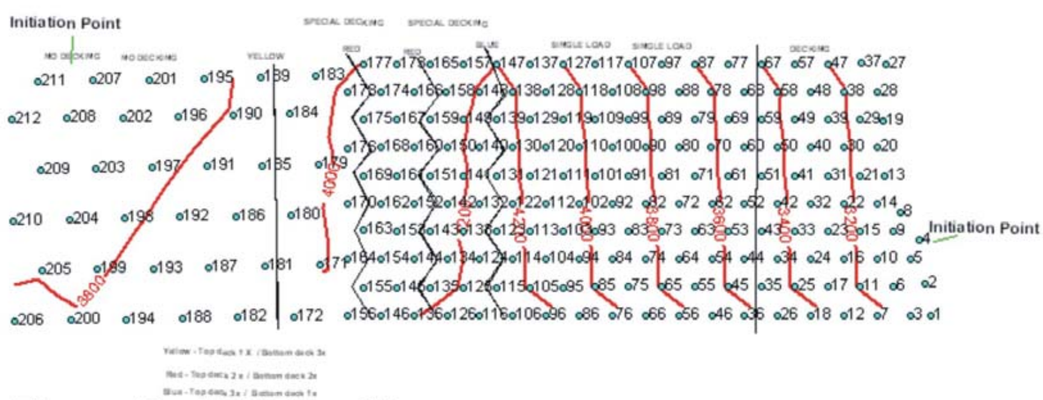

Figure 12. - Initiation Wave

In this case, the initiation-timing wave is shown in red (see Fig. 12). The first initiation begins on the right side of the blast into the open ore face. A second initiation front starts on the left side of the pattern and progresses toward the separation zone. 90 MS were used down the face with 10 MS between holes.

After conducting a safety procedure, clearing the mine and setting off a small test charge to verify atmospheric conditions from monitoring sites, the blast is initiated from a remote location outside the safety personnel limit. The second initiation wave arrives in the separation zone and throws the rock wedge to the left off the underlying ore. Blast 1435_0507 is shown during initiation with the separation at the center of the blast in Fig. 13.

Figure 13. – Blast 1435_0507

The final result is a well-defined separation zone, easily identifiable for our shovel operators as shown in Fig. 14.

Figure 14. - Final Separation

Previous Work

The past two decades have witnessed the maturation of electronic detonators. An outgrowth of the space program, the technology has gained acceptance more recently in blast initiation systems. Documentation of performance and subsequent economic implications can be found in the literature.

Cunningham (2004) has summarized 20 years of electronic detonator experience. McKinstry et al (2002) reported an 11% loading productivity increase, reduced dilution and increased mill throughput in Nevada open-pit gold. Nojiri et al (2002) reported a 30% reduction in loader cost in Brazilian iron ore. Brent et al (2003) reported cast to final success of 37.5% while maintaining environmental control. Gitzlaff (2005) reported on the early trials that began in October of 2004. This work laid the foundation for subsequent tests at United Taconite that focused on reducing ore dilution through the use of novel timing schemes.

Conclusion

In conclusion, United Taconite is realizing significant blast control and separation benefits from digital delay blasting. Controlling the movement of blasted material, consistent with the experience reported by McKinstry(2002) and Brent(2003), is an important advantage of programmable timing. In Mesabi iron ore operations, reduced ore dilution may well be the prime economic consideration for using electronic detonators. The learning curve may be a significant challenge for some blasting operations. Vendor support is a critical component for success. We will continue to utilize electronic delays, evaluating the advantages and making improvements. With the implementation of a new computerized dispatching system and installation of a WipFrag™ imaging system, the mine will be able to evaluate energy control as it applies to fragmentation, comparing the advantages of electronics over pyrotechnic blasts.

Acknowledgements

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