An Explosion in Mining

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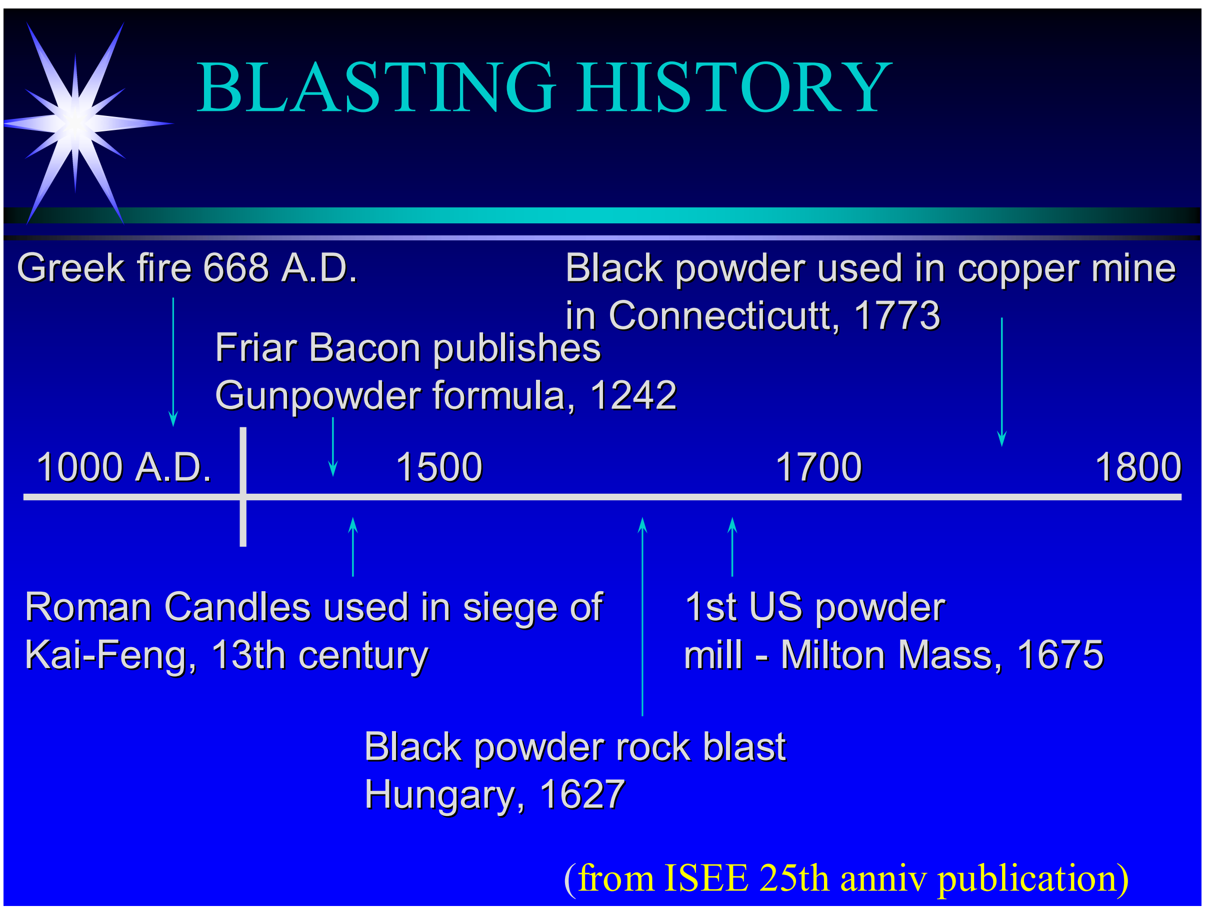
Introduction

Lake Superior mines will consume in the excess of 200 million pounds of explosives in the year 2000. I would like to spend a little time discussing the history of explosives usage and current challenges.

The mines of the Lake Superior iron ranges have seen many changes in mining made possible by the advent of modern blasting agents. When Michigan production began, there was no dynamite nor any blasting caps. Safety fuse was but 20 years old. New products and methods have quickly found their way into iron ore operations.

Timeline

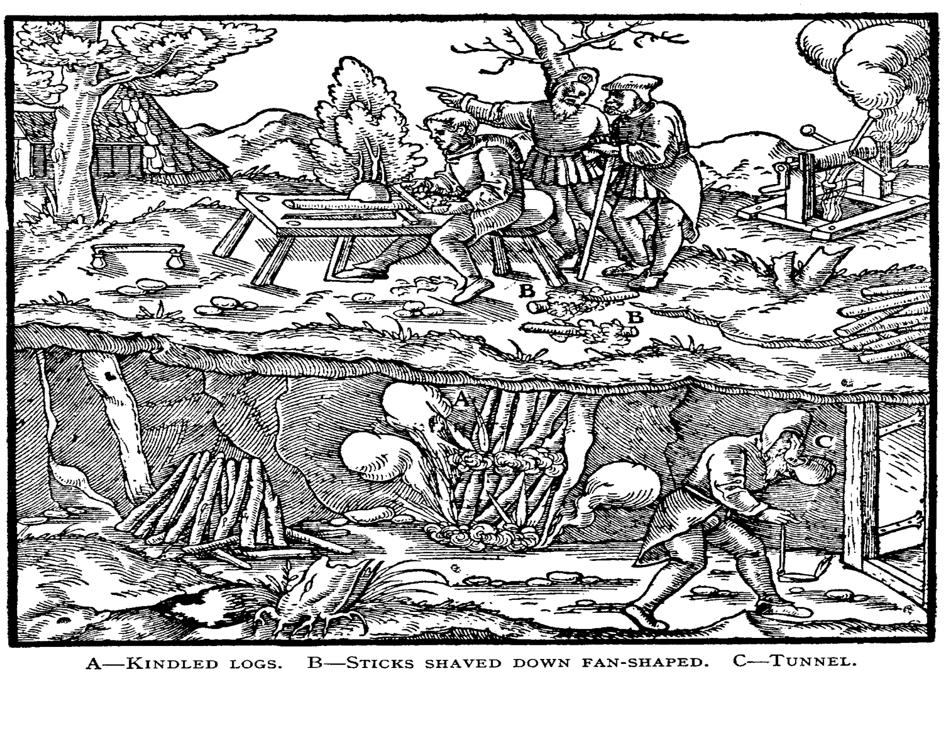


The attached timeline, adapted from the International Society of Explosives Engineers, charts developments in blasting for the past 1300 years. 'Greek fire' is often cited as the first explosive material invented.

“Greek fire was a weapon that had a decisive tactical and strategic impact in the defense of the Byzantine Empire. It was first used against the Arabs at the siege of Constantinople of 673. Greek fire was a liquid that ignited on contact with seawater. It was viscous and burned fiercely, even in water. Sand and--according to legend--urine were the only effective means of extinguishing the flames. It was expelled by a pump-like device similar to a 19th-century hand-pumped fire engine, and it may also have been thrown from catapults in breakable containers. Although the exact ingredients of Greek fire were a Byzantine state secret, other powers eventually developed and used similar compositions. The original formula was lost and remains unknown. The most likely ingredients were colloidal suspensions of metallic sodium, lithium, or potassium--or perhaps quicklime--in a petroleum base.

Greek fire was particularly effective in naval combat, and it constituted one of the few incendiary weapons of warfare afloat that were used effectively without backfiring on their users. It may have been used following the sack of Constantinople by Venetian-supported crusaders in 1204, but it probably disappeared from use after the fall of Constantinople to the Turks in 1453.”

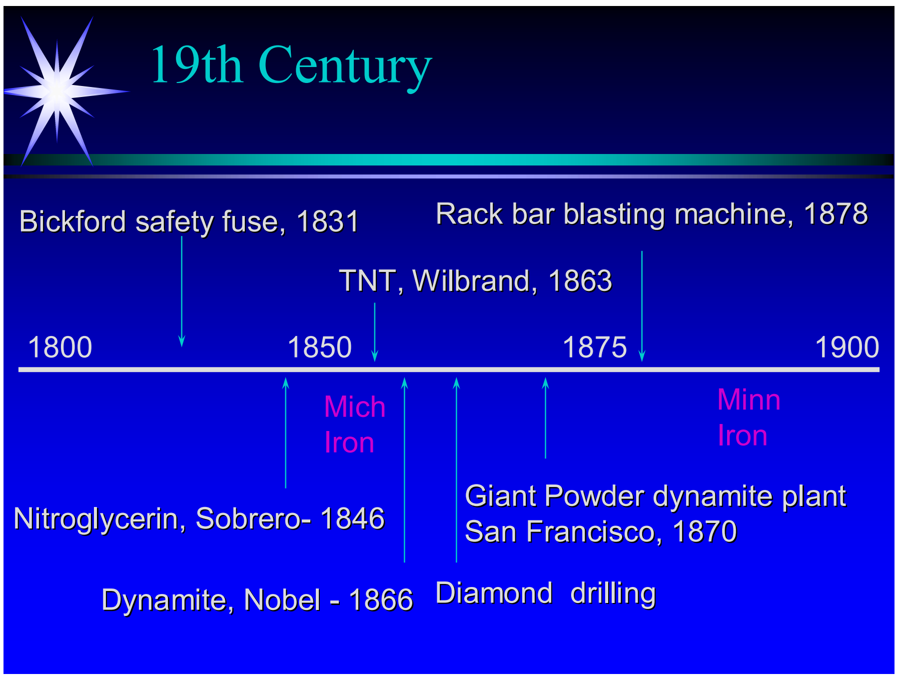
Encyclopaedia Brittanica



A—Kindled logs. B—Sticks shaved down fan-shaped. C—Tunnel.

Despite the development of Greek Fire and black powder, mining was carried on with older methods for centuries. In 1556, Agricola describes European mine firing':

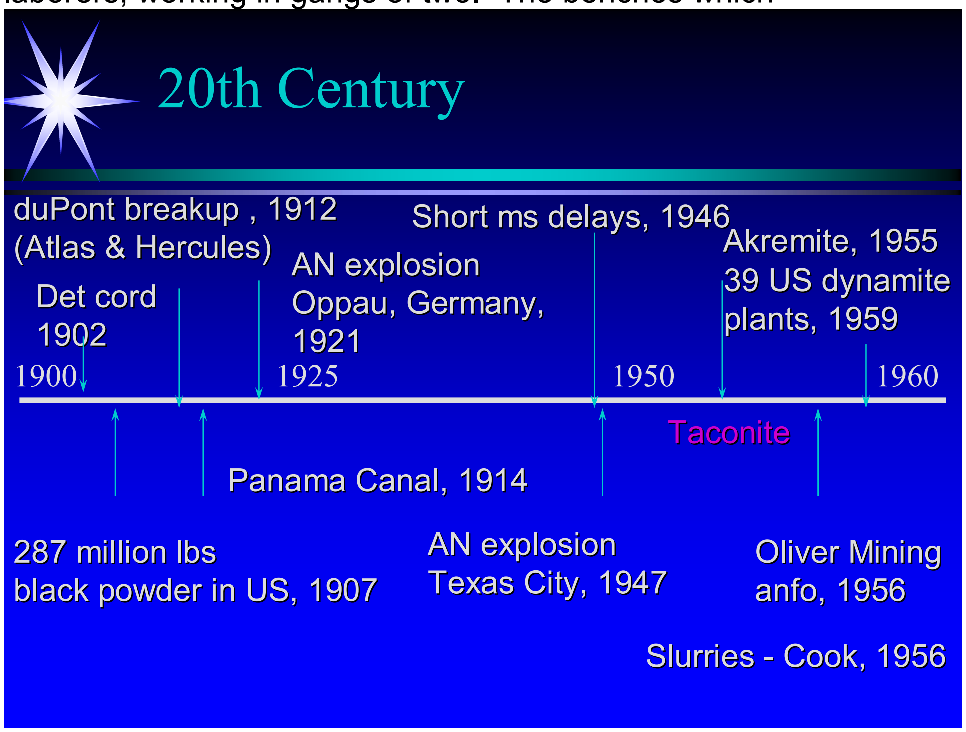
> "Even if a vein is a very wide one, as tin veins usually are, miners excavate into the small streaks, and into those hollows they put dry wood and place amongst them at frequent intervals sticks, all sides of which are shaved down fan-shaped which easily take light, and when once they have taken fire communicate it to other bundles of wood which easily ignite.
> While the heated veins and rocks are giving forth a foetid



> vapour and the shafts and tunnels are emitting fumes, the miners and other workman do not go down into the mines lest the stench affect their health or actually kill them…The Bergmeister, in order to prevent workman from being suffocated, gives no one permission to break veins or rock by fire in shafts or tunnels where it is possible for the poisonous vapour and smoke to permeate the veins or stringers and pass through into neighboring mines which have no hard veins or rock. As for the part of a vein or the surface of the rock which fire has separated from the mass, if it is overhead, the miners dislodge it with a crowbar, or if there is still some degree of hardness, they thrust a smaller crowbar into the cracks and so break it down, but if it is on the sides, they break it with hammers."(Agricola, p. 120)

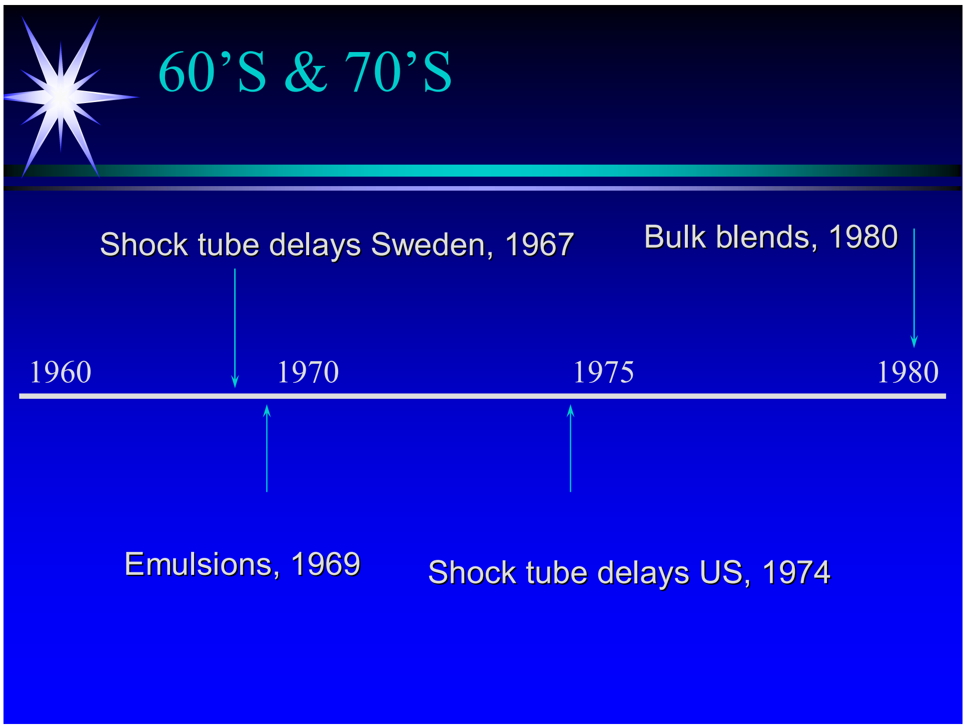
Even though the formula for gunpowder was published in 1242 in England and written about in Germany in 1544; it wasn't until 1627 that rock blasting was done in Hungary. Jumping ahead some 250 years to the early days of the Mesabi Range, we see dynamite has just come into use, but drilling is still done by hand:

> "The benches are drilled and blasted by a regular crew of 'gopher holes', consisting of 10 to 30 men, common laborers, working in gangs of two. The benches which

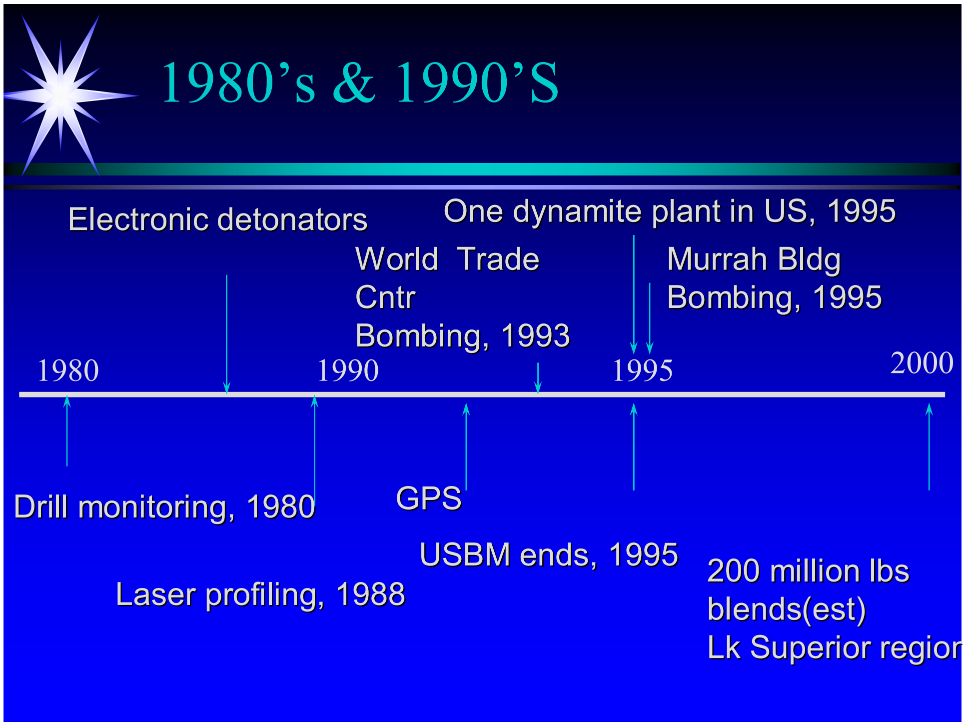


> range in 15 to 25 feet in height, are riddled with holes that are 15 to 25 feet deep, spaced 15 to 25 feet apart. The collar of the hole is at the base of the bank and the hole points downward at an angle of 15 to 20 degrees minimum spacing for high bank and hard material maximum spacing for lower and softer banks.
>
> These holes have a diameter of 14 inches. Drilling through the loose stuff is accomplished by an ordinary round-pointed shovel with sides slightly turned up, provided with a long pole handle, 20 to 25 feet long , with a 2 ½ inch diameter. As the ground becomes harder, 24-foot auger drills are used. If the material needs loosening up, a stick or two of dynamite is dropped in and exploded and the loose material removed with a shovel. Drilling time or such a hole varies from 2 to 12 hours, according to the ground; wages, $2.00 for a 10-hour day.

Du Pont black blasting powder is used, from 6 to 8 kegs (25 pounds) to a charge. Two men constitute a loading crew; they load from 3 to 7 holes in a day. The powder is pushed into the hole on a rectangular spoon made of 1-inch lumber, 32 inches long, and 3 by 3 inches inside dimensions, fastened to a 25-foot handle…The detonator consists of 5 sticks of 60 percent dynamite tightly wrapped together, two of which have electric caps…. The hole is tamped with gravel…. The holes are fired in batteries of 3 to 14, usually 5 to 8 at a time."



These are but a few snapshots of the long history of explosives development. Taconite development began during the waning days of dynamite's role as the explosive of choice. The ascension of ammonium nitrate based products in the 1950's and 1960's occurred, in no small part, due to efforts on the Mesabi Range. Dr. Cook developed water gels in 1956 and by 1960, bulk trucks were used to place them. Watergels were followed by emulsions in 1969, which in turn gave way to anfo blended with emulsions in 1971. By 1980 the bulk anfo blends that we are familiar with today were available.



Challenges

Technology

The following important tools have been introduced in the past 2 decades:
- Drill Monitoring
- Laser Profiling
- GPS
- Electronic Detonators

These devices have been described in detail over the past several years. Unfortunately, their introduction coincided with a period of low commodity prices and staffing reductions. As a result, much of the technology's promise remains unfulfilled. Competing suppliers offer various alternatives, waiting for cues from customers. Customers, with limited staffing, remain reluctant to commit man-hours to technologies that continue to evolve. Standardization requires that someone go ahead and make the first trials.

Blasting is slower to change than other areas due to safety considerations. Perhaps, the demographics play a role as well. Blast crews are populated with experienced employees who have developed a comfort level with current methods and may be reluctant to change due to safety or convenience issues.

Public uneasiness

Following bombings at La Guardia Airport and the World Trade Center in New York and more recently in Oklahoma City, there exist a public uneasiness concerning explosives. Combine the natural fascination people have with explosives with this uneasiness and you have an attention getting combination that can be tapped repeatedly by evening newscasters, newspaper editors and politicians; none of whom have the expertise to discuss blasting issues.

It is critical that the public does not view legitimate users of explosives as part of the problem. However, when lost or stolen explosives show up at crime scenes or loss of life occurs in blasting operations; we ‘get tarred with the same brush’. In short, we are viewed as part of the problem and our input in the debate is viewed only as self-serving.

Eliminating poor practices

The Iron Range has an enviable safety record and sophisticated work force when it comes to blasting. That doesn’t mean there is not room for improvement. Poor field controls, overloaded holes, failure to measure powder rise, securing explosives, dropping of assembled boosters, stemming practices and poor misfire procedures have occurred in the past five years. Before we can move ahead and capitalize on the opportunities afforded through new technology, we must form as solid foundation of good practices.

Train and motivate blasting personnel

Recent cost cutting efforts have been effective in flattening corporate structures and pushing down more responsibility to people in the field. Unfinished work in this area includes increased investment in the people in the field. Training must address both the ‘how’ and the ‘why’. Just providing technical training (the how) will not be enough. Motivation (the why) is equally important since every blasthole must be properly loaded. The Lake Superior district loads in the order of 100,000 blastholes each year. If quality standards were at 99%; that would still leave 1,000 possible misfired holes each year. Clearly, high standards are essential.

Integrate blasting with the mining process

Mine managers have difficulty in weaving blasting into the schedule of mining. Drilling delays and blasting delays, due to weather, combine to complicate scheduling of shots. Decision makers often lack experience in blasting operations. Cost reductions through increased used of less water resistant products are available, but haphazard scheduling requires blasters to use more expensive, water resistant products in case long sleep times become necessary. Buffers (muck left on the face) tend to choke rock movement, resulting in higher and tighter muckpiles. Mine operations will benefit if a balance is struck between blasted inventory requirements, blending and buffers. If the entire face cannot be mucked, at least the opening portion of the blast should be afforded some relief.

Integrate total comminution costs

A rational approach to stepwise fragmentation is now within reach. If crushing is, in fact, at least 20 times more efficient than grinding; then flowsheets must be adjusted accordingly. Obviously, expensive crushers and mills cannot be replaced overnight, but research and development can be the first step. For more details see reference, “The Effect of Fragmentation on Downstream Processing Costs”.

Tap full potential of drill monitoring, GPS and laser profiling and electronic blasting caps.

“Close is good enough” is an outdated motto. Precision in every step of the fragmentation process is now available, affordable and necessary. Drill monitoring removes the unknown element of geologic variability from blast design. Unfortunately, drill monitors do not speak in a language understandable to blasters. Output is in feet per minute, torque and pounds per square inch. Once these numbers are translated into: required burden, spacing and powder factor; blast designs can match actual rock conditions. The manufacturers have provided the tools, now mines have to commit the man hours for interpretation.

GPS is a valuable tool for mining and especially important for blasting. Without GPS, detailed drill monitoring information is difficult to use in the field. When drills, blasters on the ground and powder trucks have an accurate location; hole loading can be individualized and precise.

Pyrotechnic blasting caps do not fulfill the basic requirements for iron ore blasting: sequencing and separation of charges. Rock shifting has been documented on high-speed film up to 350 feet ahead detonating holes. At 30 feet of spacing, that is 350/30 or about 12 holes ahead. Now, combine that with a need for at least 2 millisecond per foot for relief to calculate the time needed between holes - 60 ms. But, to achieve 12 holes of separation between arming and detonation, multiply 12 times 60 ms or 720 ms downhole. Given a 5% standard deviation in timing accuracy for pyrotechnic delays, that means that to achieve 99% confidence; the spread is 3 standard deviations or a 15% which is 108 ms (15% of 720). That means the downhole inaccuracy obliterates the surface time and some holes fire out of sequence.

There is no simple remedy, since shortened delay times downhole decreases cutoff protection and shortened surface timing increases the incidence of out of order timing. For these reasons, highly accurate electronic caps are very important. They are expensive today, but in the long run, they will be cheaper to produce than conventional delays.

Optimize blasting to limitations of lighter and shorter loading equipment

Rope shovels have been partially replaced by loaders and hydraulic shovels in Michigan and Minnesota. The hydraulic shovels purchased to date, have less breakout force, are lighter and require a shorter bank height. These excavators need a looser muckpile. In their current application, they tend to dig away the toe of the bank which results in “toppling chimneys” if the bank is tight and tall. The threat of rockfalls and the rough ride due to teetering of the shovel, has made operators unreceptive to hydraulic shovels. Lake Superior blast designs have been fundamentally inefficient due to wide spacings, short benches and large hole diameter. Further reduction in bench height to accommodate hydraulic shovels will result in even less efficient blast geometry.

The solution may be smaller holes drilled closer together or higher benches which are shot so as to spill the rock to a low bank. Three-row patterns or narrower may be needed to accomplish this.

Musings

In closing , I would like to offer a few thoughts on how mines can move ahead. Number one, most overnight success stories are 20 years in the making. Research and development needs to be accelerated now to make up for the shortfall since the retrenchment of the 1980’s. Number two, we have to remember that the real resource is innovation. Through empowerment and ownership there is an infinite pool of new ideas. There are more people today than ever which means there are more minds working on solving problems. Let’s not be haunted by bigger than life figures from the past; great discoveries await us. Committees and teams are unmatched for developing ideas, but <u>individual</u>

champions cause things to happen.

This district has truly been a part of the explosion in mining. It is now our job to insure that this famous district has more than just a historical significance.

References

Agricola, Translated from the first Latin edition of 1556 by G.Hoover, H. C. and Hoover, L. H. De Re Metallica, Dover Press,1950

Blasters' Handbook, 17th Edition, International Society of Explosives Engineers, Cleveland, OH 1998

Eloranta, J.W. 1994, Selection of Powder Factor in Large-Diameter Blastholes, Proceedings of the20th conference of Explosives and Blasting Technique, Austin, TX Jan 30 - Feb 3, 1994. International Society of Explosives Engineers, Cleveland, Ohio, pp 255-272

Eloranta, J.W. 1995, The Effect of Fragmentation on Downstream Processing Costs, proceedings of Explo95 Conference, Brisbane, QLD, Australia, Sept. 4-7 pp. 25-28

Eloranta, J.W. 1999, Blasting Down the Cost of Taconite Pellets. Proceedings of The 72nd Annual Meeting of the Minnesota Section of the SME, Duluth, Minnesota, 1999

Encyclopaedia Brittanica, CD Rom 1999 Multimedia Edition

Simon, J. L., The Ultimate Resource Princeton: Princeton University Press, 1981; 2nd edition, 1996.