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Environmentally motivated tracking of geologic layer movement during bench blasting using discrete element methods*

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ABSTRACT: The blast-induced movement and final location of geologic layers that may cause environmental problems can be predicted using discrete element methods. This prediction capability can be used by mine operators to locate the material in the muck pile during excavation which would allow encapsulation to prevent groundwater infiltration.

1 INTRODUCTION

Open-pit mining produces the majority of the coal marketed by the U. S., both domestically and abroad. An increasing emphasis on environmentally sound mining practices makes it necessary to be innovative in applying new technologies to open pit mining. An important challenge is ground water acidification attributed to geologic layers, typically a shale, that have a higher-than- average pyrite content. The acidification occurs as bacteria interact with the pyrite, producing hydrogen-sulfide which raises the PH of ground water flowing through the material. Groundwater acidification is accelerated significantly in open-pit mines as the relatively impermeable shale layers are rubblized by blasting, greatly increasing the hydraulic conductivity of the material. A viable solution for mine operators is to separate the pyritic material during muck-pile excavation and encapsulate it in some manner to prevent groundwater interaction. This solution depends on being able to locate the pyritic material in the post-blast muck-pile. The movement and final location of this material was analyzed by using a discrete element computer simulation.

2 DISCRETE ELEMENT MODELING

DMC is a two-dimensional spherical element discrete motion code that was originally developed by Taylor and Preece (1989 a&b and 1992) for modeling the motion associated with rock blasting. Spherical element bulking mechanisms have been added to allow spherical elements to behave more like rocks (Preece and Taylor, 1990). This program has been used for modeling a number of different blasting applications including: 1) oil shale retort blasting (Preece, 1990 a&b), and 2) bench blasting in rock quarries and coal mines (Preece and Knudsen, 1992b), (Preece,1993c). A concept called spherical element packing angle (Preece, 1993b) has been developed for more accurate modeling of bedding planes in sedimentary rocks. The current version of DMC has also been used to examine the influence of row delay timing on blasting

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induced rock motion (Preece, 1994a). DMC has been coupled with a gas flow computation capability so that the explosive loading is automatically treated when an explosive is specified along with its physical parameters and equation-of-state (Preece and Knudsen, 1992a) (Preece, 1993a). DMC has been used by industry to optimize blast designs for maximum movement of material. It compares favorably with other computer programs used to predict the results of a blast (Chung, McGill and Preece, 1994).

3 EXAMPLE PROBLEM DESCRIPTION

The example problem presented here is a coal mine bench blast at a mine located in the central Appalachian coal region. Actual field data from the mine including geometry, geology, blast design, and percent-cast were employed to guide the simulations presented here.

3.1 *Bench Blast Configuration*

Figure 1 illustrates a cross-section schematic of the bench blast where the second layer above the coal is a pyritic sandy shale. The mine operators load the blastwell with explosives above and

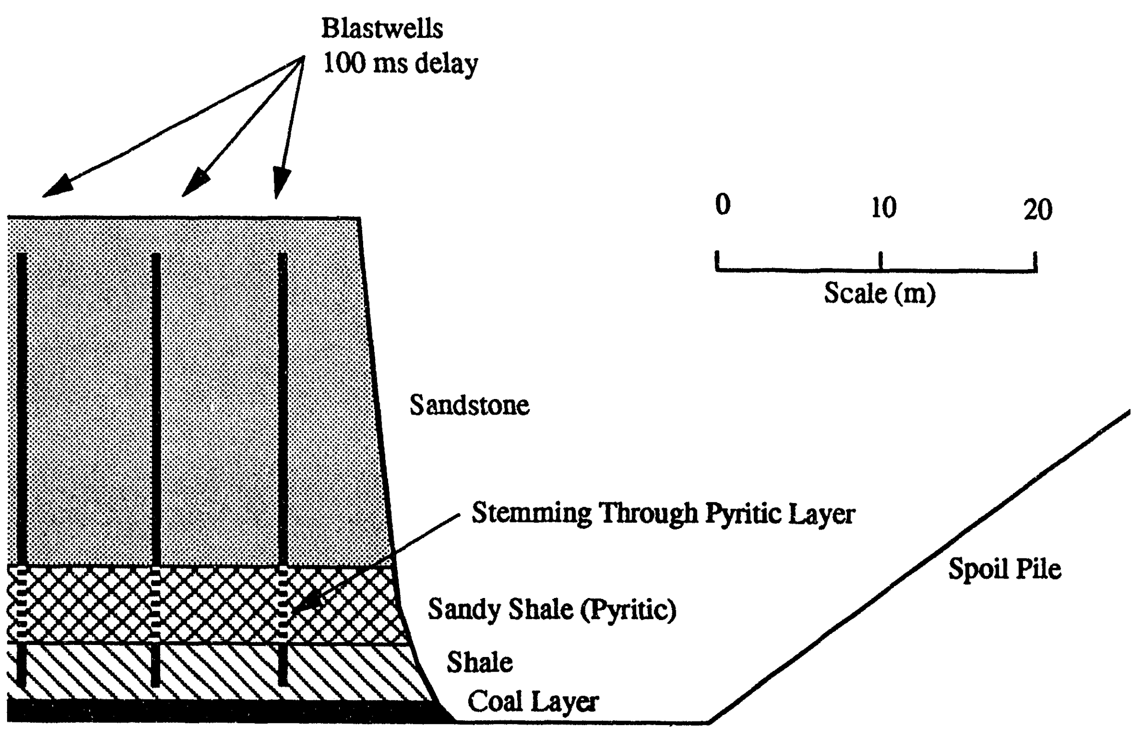

Figure 1: Schematic of Bench Blast Example Problem

below the pyritic layer. A deck of stemming material (gravel or drill cuttings) is placed through the pyritic layer to prevent it from being loaded directly by the explosives. That practice is modeled in this simulation. The induced motion in the pyritic layer results from frictional drag by the two layers above and below.

3.2 *Definition of Percent-Cast*

Figure 2 illustrates the definition of percent-cast, a concept commonly used to measure blast-induced rock motion. The cast-line is parallel to the angle of repose of the spoil pile and intersects the bottom of the bench face. Percent-cast refers to that portion of the overburden that is beyond the cast-line and thus resides in its final position, not requiring any rehandling. In this study the motion and final location of the pyritic layer is of greatest interest. Pyritic material that has moved very little will be easiest to recover during muck-pile excavation. Any of this material that has moved beyond the cast-line will be difficult to recover for two reasons: 1) excavation is normally not done beyond the cast-line, and 2) the material tends to scatter with increased motion which is indicated by a higher percent cast for the material. Thus, movement of pyritic material beyond the cast-line will be used as a measure of recoverability, and comparisons will be made between the overall percent-cast and that of the pyritic layer.

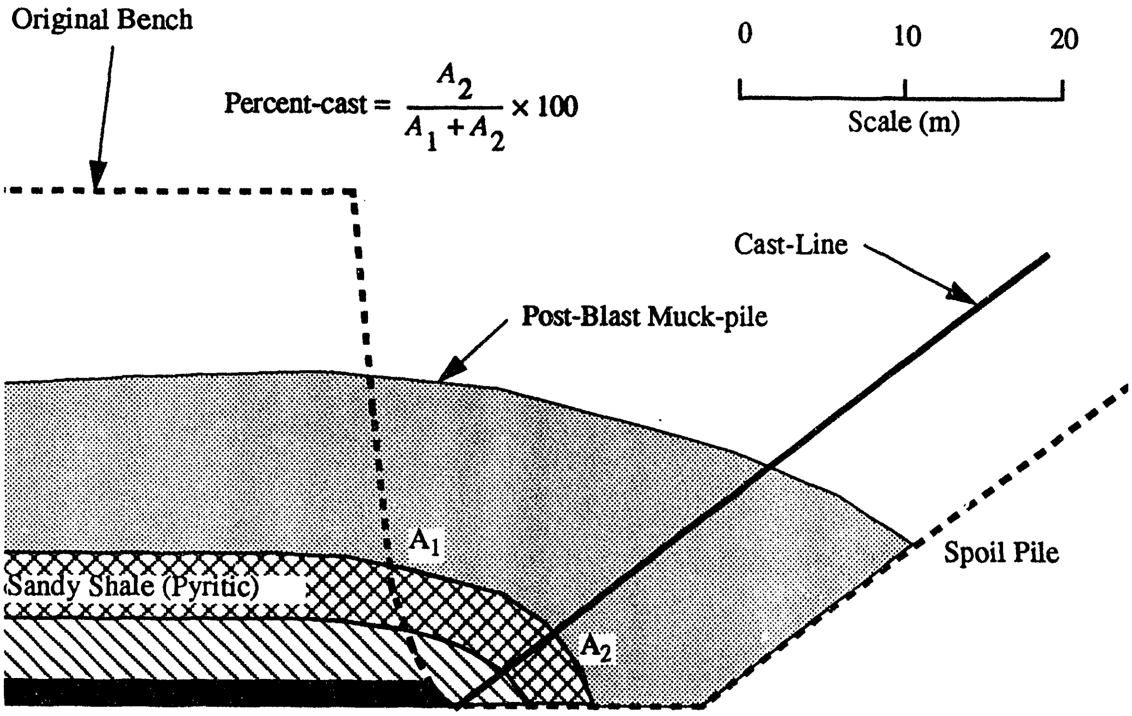

Figure 2: Definition of Percent-Cast Where A_2 Represents Material Beyond the cast-line, A_1 Represents Material in Front of the cast-line. Percent-Cast for Individual Materials are Determined in a Similar Manner.

4 ROCK MOTION SIMULATION

4.1 *Discrete Element Model*

The spherical discrete element model used in the rock motion simulation is illustrated in Figure 3. The coal is represented by the darkest layer of spheres just above the pit floor. The pyritic layer, which is of most interest in this calculation, is represented by the dark spheres constituting the second layer above the coal. The spherical elements beneath the coal and extending under part of the pit floor are included to move the hard bottom boundary away from the area where the action will occur during the simulation. Material parameters used in this calculation are given in Table 1, and explosive parameters are given in Table 2. In Table 2 the burden is the distance from the blastwell to either the free face (for the front row) or the blastwell row immediately in front of the current row, the spacing is the distance between blastwells parallel to the free face, and the powder factor is the mass of explosive per unit volume of rock. It is determined

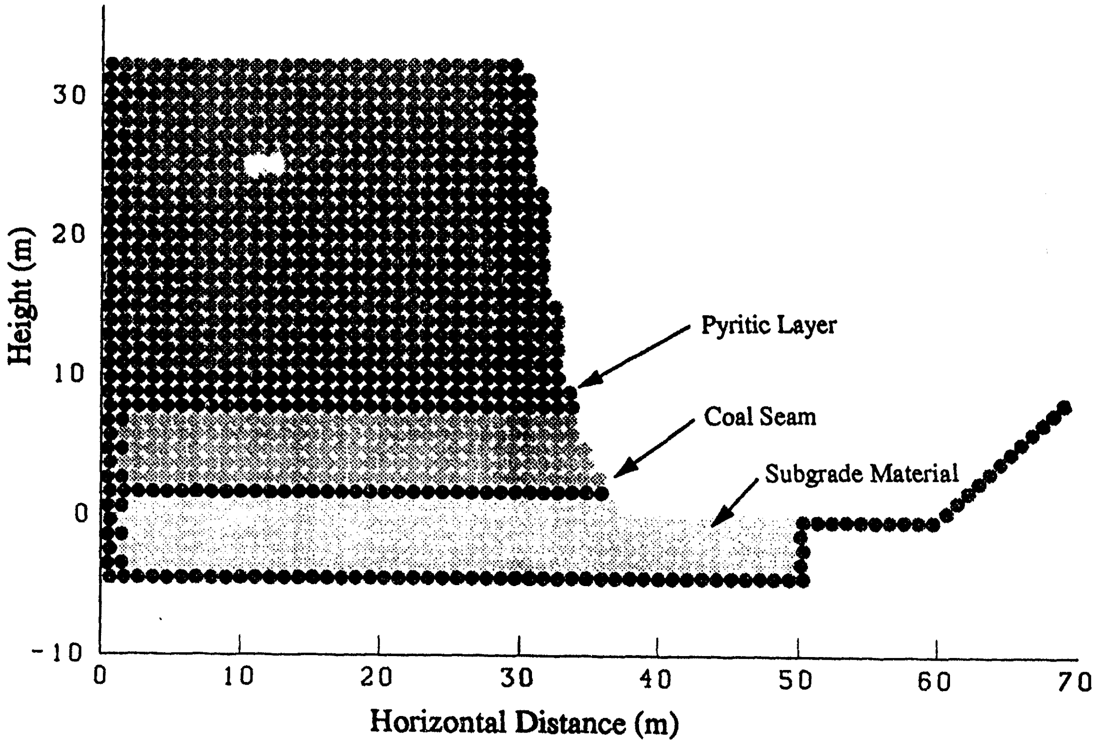

Figure 3: Spherical Discrete Element Model

Table 1: Material Properties

Material	Thickness (m)	Young's Modulus (GPA)	Poisson's Ratio	Specific Gravity
Coal	1.31	50.0	0.25	1.5
Shale	4.92	40.0	0.30	2.2
Sandy Shale	2.62	40.0	0.30	2.2
Sandstone	24.61	50.0	0.21	2.2

Table 2: Blast Design Parameters

Row No.	Burden (m)	Spacing (m)	Explosive	Powder Factor (Kg/m^3)	Hole Dia. (mm)	Row Delay (ms)
1	6.40	9.88	H-ANFO 60/40*	0.64	229	0
2	10.66	9.81	"	0.39	229	100
3	11.30	10.1	"	0.36	"	"

*Mixture ratio, emulsion to ANFO

from the blastwell geometry and explosive density along with the burden, spacing and face height. These values are typical for this type of mine. The powder factor is higher in the front row because the burden has been reduced compared with subsequent rows. This is a common practice to obtain better movement of the front row so that it doesn't choke the flow of subsequent rows.

4.2 Simulation Results

Two parameters were varied between simulations: 1) explosive loading to produce more or less rock motion and a different percent-cast for each simulation, and 2) the height of the pyritic layer above the pit floor. Simulations with different explosive loadings resulted in a relationship between percent-cast for the entire blast and percent-cast for the pyritic layer.This relationship is indicative of the percentage of pyritic material that moves beyond the cast-line and will likely not be recovered. Spherical element models with three different pyritic layer heights above the pit floor were modeled to determine the influence of vertical layer position on material scattering. Four snapshots in time, 100ms, 300ms, 1.0s and 7.0s, for the simulation with the pyritic layer closest to the pit floor and with a cast of 30% are illustrated in Figure 4.

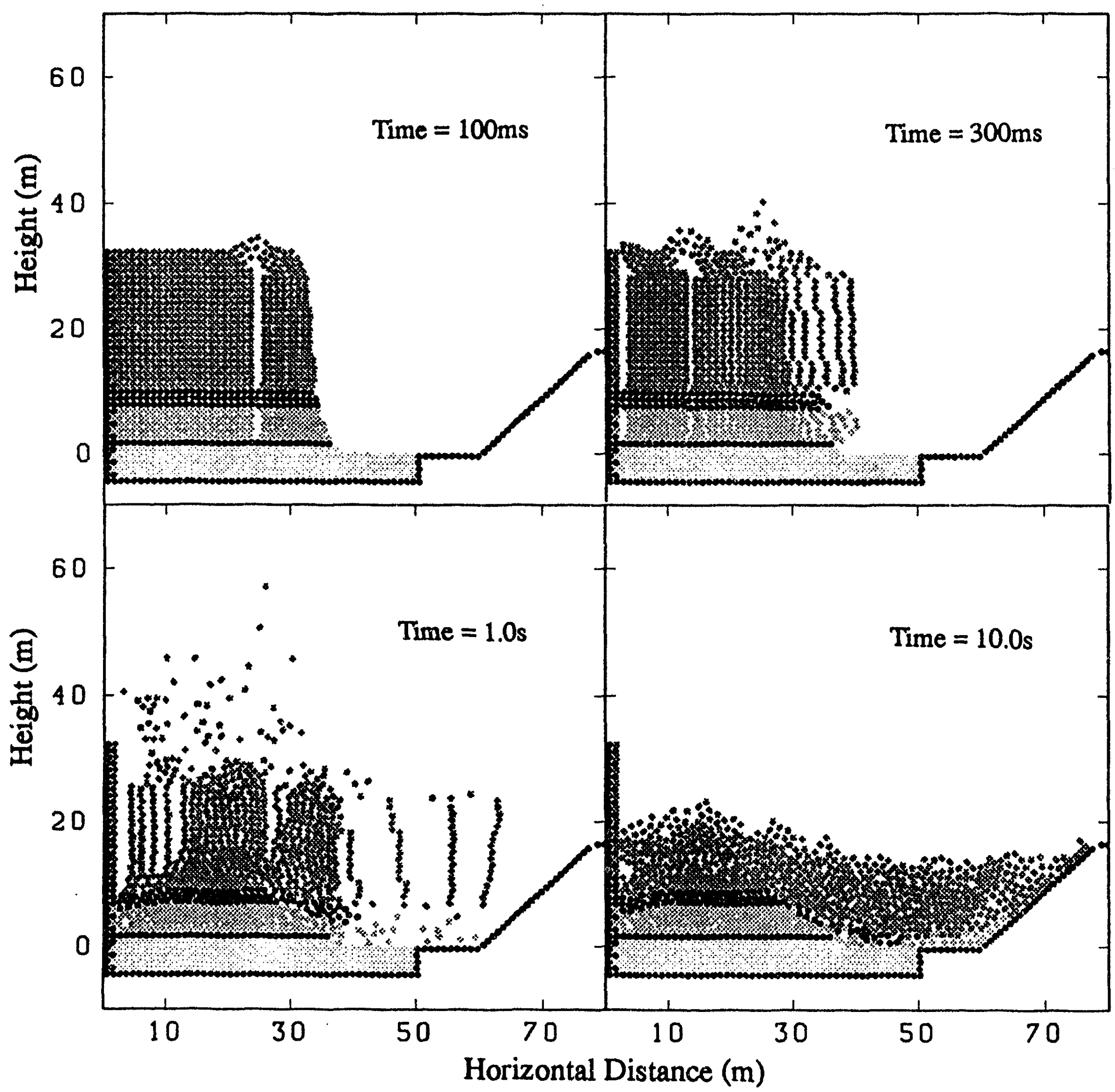

Figure 4: Rock Motion Simulation For Pyritic Layer Close to Pit Floor.

The 10.0s frame in Figure 4 shows the predicted final muck-pile shape and indicates that the material in the pyritic layer remains basically in place with only a small portion (14%) spilling into the pit, beyond the cast-line, where it will be difficult to recover. The simulation with the pyritic layer highest off the pit floor is illustrated in Figure 5 with two time snapshots, 100ms and 10.0s, Again the 10.0s frame presents the final muck-pile shape and shows considerable stretching of the pyritic layer and scattering amongst the surrounding material. It is evident from Figure 5 that this material would be almost impossible to locate in the post-blast muck-pile and points to vertical layer position as an important factor defining retrievability.

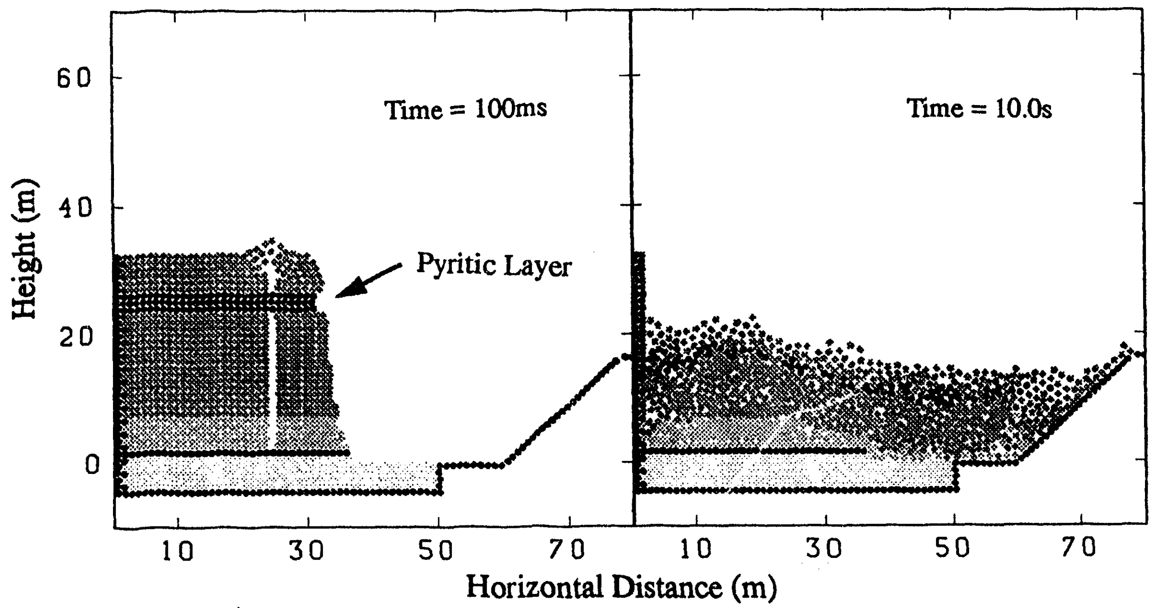

Figure 5: Rock Motion Simulation For Pyritic Layer High Off the Pit Floor

Results derived from all of the simulations are presented in Figure 6 in the form of pyritic layer percent-cast versus overall percent-cast for the three different layer vertical positions. Several conclusions can be deduced from the data in Figure 6. First, pyritic material loss due to a final position beyond the cast-line decreases with reduction of overall percent-cast. Second, the relationship between pyritic layer percent-cast and overall percent-cast changes with layer height above the pit floor. When the layer is close to the pit floor its' percent-cast is significantly less than the overall percent-cast. If the pyritic layer is relatively high in the bench its' percent-cast is greater than the overall percent-cast. Even though only three vertical layer positions were considered, the trend of more horizontal motion with increasing layer height is clear. What is not evident in Figure 6 is material irretrievability due to layer stretching and mixing with adjacent layers that increases with height above the pit floor. This phenomenon can be observed in Figures 4 and 5.

5 CONCLUSIONS

A discrete element computer code, DMC, has been employed for tracking geologic layer movement during bench blasting. Geologic layers requiring tracking are those that have adverse environmental effects such as accelerated ground water acidification. Even though blasting is a dynamic chaotic process, several definite trends in material movement have been identified. A number of DMC blast simulations have been used to demonstrate two important influences on the retrievability of material in the muck-pile, 1) overall percent-cast and 2) layer height above the pit floor. Pyritic layers that are relatively low in the geologic strata of the bench, close to the pit floor, are the most amenable to location prediction and recovery during muck-pile excavation. Layers high in the geologic strata of the bench will experience significant horizontal movement, stretching, scattering and intermixing with adjacent layers with a low probability of location and recovery during excavation. For all layer heights the scattering increases with overall percent-cast. The allowable layer percentage loss will dictate a blast design yielding a corresponding overall percent-cast.

Even though general trends have been shown in this paper, each blasting site is unique in terms of geometry, geology and blast design. Motion simulations that include specific site parameters would be necessary to attempt material location and retrieval at different sites than the one modeled here.

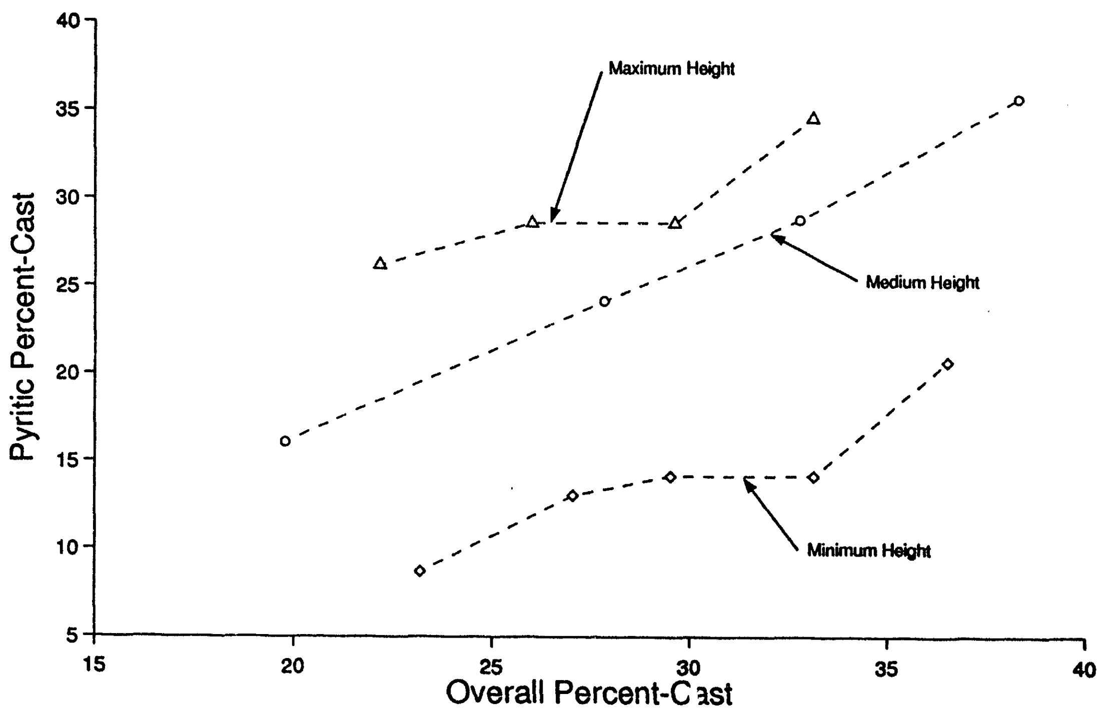

Figure 6: Pyrite Layer Percent-Cast Versus Overall Percent-Cast for Three Different Layer Heights Above the Pit Floor.

REFERENCES

Chung, S., McGill, M, and Preece, D. S., 1994, Computer Cast Blast Modeling, 20th Annual Conference on Explosives & Blasting Technique, International Society of Explosives Engineers, Austin, Texas.

Preece, D. S. & L. M. Taylor, 1990, Spherical Element Bulking Mechanisms for Modeling Blasting Induced Rock Motion, Third International Symposium on Rock Fragmentation by Blasting, Brisbane, QL, Australia.

Preece, D. S., 1990a, Rock Motion Simulation and Prediction of Porosity Distribution for a Two-Void-Level Retort, 23d Annual Oil Shale Symposium, Colorado School of Mines, Golden, Colorado.

Preece, D. S., 1990b, Rock Motion Simulation of Confined Volume Blasting, 31st U.S. Symposium on Rock Mechanics, Colorado School of Mines, Golden Colorado.

Preece, D. S., and S. D. Knudsen, 1992a, Coupled Rock Motion and Gas Flow Modeling in Blasting, Eighth Annual Symposium on Explosives and Blasting Research, International Society of Explosives Engineers, Orlando Florida.

Preece, D. S., and S. D. Knudsen, 1992b, Computer Modeling of Gas Flow and Gas Loading of Rock in a Bench Blasting Environment, 33d U. S. Symposium on Rock Mechanics, Santa Fe, New Mexico.

Preece, D. S., 1993a, Momentum Transfer From Flowing Explosive Gases to Spherical Particles During Computer Simulation of Blasting Induced Rock Motion, Ninth Annual Symposium on Explosives and Blasting Research, International Society of Explosives Engineers, San Diego, California.

Preece, D. S., 1993b, Variation of Spherical Element Packing Angle and Its Influence on Computer Simulations of Blasting Induced Rock Motion, 2nd International Conference on Discrete Element Methods, Massachusetts Institute of Technology.

Preece, D. S., 1993c, Coupled Explosive Gas Flow and Rock Motion With Comparison to Bench Blast Field Data, Fourth International Symposium on Rock Fragmentation by Blasting, Technical University, Vienna, Austria

Preece, D. S., 1994, A Numerical Study of Bench Blast Row Delay Timing and Its Influence on Percent Cast, Proceedings of the 8th International Conference of the Int. Assoc. for Comp. Meth. and Advances in Geomechanics, West Virginia University, Morgantown, West Virginia

Taylor, L. M. & D. S Preece, 1989a, DMC - A Rigid Body Motion Code for Determining the Interaction of Multiple Spherical Particles, Sandia National Laboratories, SAND88-3482.

Taylor, L. M. & D. S Preece, 1989b, Simulation of Blasting Induced Rock Motion Using Spherical Element Models, First U.S. Conference on Discrete Element Methods, Colorado School of Mines, Golden, Colorado.

Taylor, L. M. & D. S Preece, 1992, Simulation of Blasting Induced Rock Motion Using Spherical Element Models, Engineering Computations, Vol. 9, No. 2.

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