NIPES

Advances in Engineering Design Technology

Journal homepage: www.nipesjournals.org.ng

Control of Ore Loss and Ore Dilution at Surface Mine Using Blast Movement Technology

George Agyei[a] and Enock Kaku Amosah[b]

[a, b] University of Mines and Technology, Department of Mining Engineering, Box 237, Ghana
Corresponding Author: gagyei@umat.edu.gh

ARTICLE INFORMATION

Article history:
Received 22 February 2022
Revised 28 February 2022
Accepted 08 June 2022
Available online 15 June 2022

Keywords: *Blast, Monitoring, Loss Dilution, Movement, Ore, Waste*

https://doi.org/10.37933/nipes.a/4.2.2022.1

https://nipesjournals.org.ng

ABSTRACT

Blast Movement Monitoring (BMM) system is a new method of determining material movement during blasting in order to minimise ore loss, ore dilution and misclassification. The BMM system has been introduced at Adamus Resources Limited (ARL), Ghana. The essence of the investigation, therefore, is to find out the possible causes of ore loss and ore dilution at the mine, propose possible solutions to these ore loss and ore dilution and analyse the effects of blast induced movement on ore blocks with the use of Blast Movement Technology (BMT). Data was collected on BMM of the mine for analysis, and it was observed that, the bottom flitch of the blasted material moved more than the top flitch in the horizontal direction while the reverse was the case for the vertical movement. Continuous use of the system as a grade control practice, is, therefore, been recommended for the mine, especially with shot containing ore. Also, the use of BMT should be properly supervised to prevent improper installation of the balls.

1. Introduction

The aim of rock excavation in an open pit mine is to produce an optimum mill feed with minimum dilution to maximize recovery at a minimum operating cost. Ore dilution and ore loss are the most important factors affecting the economy of mining project at Adamus Resources Limited (ARL), Nzema Mine, Ghana. Controlling ore loss and ore dilution is critical for all mining operations, otherwise can result in tens of millions of dollars of lost revenue per year. Blasting causes movement of the rock and can be detrimental to the accurate delineation of the ore and waste regions within the resulting muck pile. Failing to account for post-blast movement means that ore is sent to waste dump (ore loss), and waste to the mill (ore dilutionBlast Movement Monitoring (BMM) is the act and effect of determining blast movement and translating ore polygons to reveal ore displacement to achieve optimal ore yield. Blast movement changes in depth and across different ore blocks making it difficult to predict blast movement with precision for all control processes.

For blast movement to occur, the explosive force applies force equally to all directions and the rocks with the least resistance move. The movement of the rocks with least resistance act on neighboring rocks which results in bulk movement of the rock massive [1]

Dilution increases the operating cost in the mill by increasing the tonnage of material to be milled. Blast Movement Technology (BMT) is a novel method of determining material movement during blasting in order to minimize ore loss and ore dilution [2].

Results in [3] qualified the blast movement at three major porphyries and manto copper mines in South America. The Author did a comparative analysis of in Situ polygons to the translated polygons to evaluate the effect of blast movement or ore loss, dilution and misclassification; and how even low values of ore loss up to 5% can have a significant financial loss to the mining operations.

Blast movement analysis in [4] found that the ore loss that would occur at selected ore blocks by using blast movement monitors and polymer pipes It was revealed that the pipe tracking resulted in poor recovery of 32 percent as compared with 92 percent for BMM.

Damang Mine determine range of movement between 1.9 – 4.5m however, with the application of BTM, there has been a reduction in dilution, ore loss.

The authors in [5] identified blast-induced dilution as a significant grade control problem. This study determined the possible causes of ore loss and ore dilution at ARL with the use of Blast Movement Technology (BMT).

A number of mine sites and research institutions have used a range of measurement techniques with varying degrees of successes. The measurement methods can be categorised by the type of marker employed as follows: passive visual ones such as sand bags, chains and pipes, and remote detection systems, [6].

In Ghana, the use of BMM system at Newmont Ghana Gold Ltd., Ahafo Mine was validated in 2011. This work studied the application of the system at Adamus Resources Limited, Nzema Mine and analysed the benefit of the implementation of the system.

1.1 location and geology of the study area

In the Southwest part of Ghana, the Nzema Gold Mine is located approximately 70 km from Takoradi that is the Southern end of the Ashanti Gold Belt, hence the name Southern Ashanti Mine Gold Project, Ghana [7].

It is approximately 280 km West of the capital city Accra, Ghana and less than 20 km from the coast of Esiama. About 225 km from Accra on the main coast highway to Takoradi, 79 km of paved road to the Teleku Bokazo township and a further 8 km on the well maintained, weathered dusty mine access road. The mine project site can be accessed, between the village of Aluku and Salman. The regional access to the Nzema Gold Project is shown in Fig. 1.

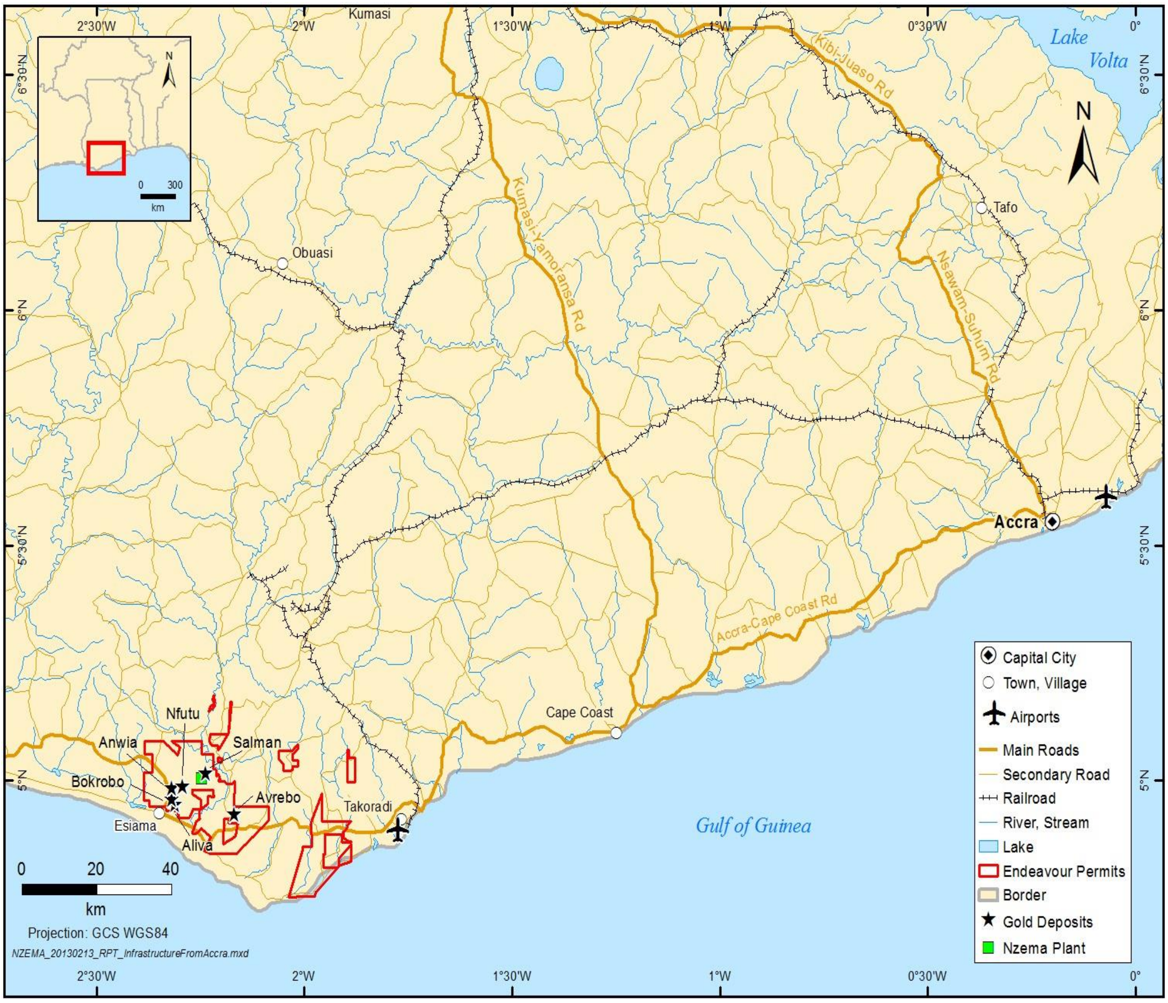

Fig.1 Access to the Nzema Gold Mine, Source: [7]

The volcanic and volcanoclastic component of the meta-volcanic Birimian stratigraphy is characterised by weakly developed bedding and early cleavage. [8]. Proximal to the Ankobra lineament, the meta-sedimentary sequence is more strongly deformed with the development of a penetrative foliation, crenulation cleavage and extensive small-scale tight to isoclinal folding. There exist boudinage quartz veins within the more ductile phyllite. Fracturing and network veining of more competent greywacke cataclastic textures are locally developed along the axes of deformation with tectonic fabric and rotated feldspars defining a dominantly dextral sense of movement [8].

Drilling at Salman suggests the presence of several sub-parallel shears including the Salman shear developed along contact between graphitic phyllite and greywacke. Fold hinges principally plunge at moderate angles to the south-southwest. Intense quartz veining is developed as stockworks within zone of significant deformation providing some insight into the deformational history and paragenesis of mineralised occurrences [9].

The mineralisation at the Nzema Gold Mine is within the Birimian rocks with minor granitic intrusions, bounded by large granitoid bodies to the west and east. The Birimian Supergroup is divided into a series of narrow northeast striking, laterally extensive volcanic "belts" separated by broader sedimentary "basins". Regional northeast striking shear zones that parallel the belt appear to be fundamentally important in the development of the Birimian gold deposits for which Ghana is well known such as Ashanti, Prestea-Bogoso, Konongo and Bibiani. The mineral deposits on the property include Salman Trend and Adamus deposits and also several smaller deposits (Bokrobo, Akropon, Nfutu, Aliva and Avrebo) [9].

Salman Trend gold deposits are believed to be associated with the same belt margin shear zones that host the other Ashanti Belt gold deposits and has many characteristics typical of these deposits. The Salman Shear Zone has placed Birimian greywacke and phyllite packages in contact. The Salman Trend gold deposits occur along a 9 km segment of the shear zone. While the Salman Shear Zone appears to be the main locus of gold mineralisation, pockets of gold mineralisation have been identified on or adjacent to other faults and structural features within the area.

The Adamus deposit is hosted by a northwest striking, northeast dipping package of greywacke (footwall) and interbedded greywacke-phyllite (hanging wall). In the western (footwall) part of the deposit, gold mineralisation is also hosted by a steeply northeast dipping granite dyke that gradually converges on the hanging wall to the northwest. The few facing directions observed suggest the metasedimentary package is overturned [13].

2. Methodology

The study utilised secondary data from ARL. Primary data was also collected from field studies using BMM instrument processing. The analyses of data were done using BMM Explorer and Surpac Software also from the Mine.

The Blast Movement Technology is more accurate in the monitoring of blast since x, y, and z axis displacement of the ore blocks can be determined. Two main procedures were followed when applying the Blast Movement Technology in mining namely Pre and Post Blast Procedures (Fig.2).

2.1. Pre-Blast Procedures

This entails all the processes and preparatory actions that were done before installing the BMMs. The following were the procedures involved:

i. Planning and drilling of monitor holes: The monitoring balls holes were drilled alongside the actual blast holes that contained the blasting explosives. The holes were drilled midway from blast holes to minimise the impact of the blast on the balls installed in them. The diameter of monitor holes drilled was about 128 mm, against 98 mm of the BMMs to ensure they don't get stuck midway in the hole during installation.

ii. Surveying holes and installing BMMs: The drilled monitor holes were surveyed with the aid of a flitch plan of the blast area and their corresponding depths were measured. The depth of monitor holes drilled was about 6 m. Installation of the BMMs was done in flitches with the lower flitch at a depth of 4.5 m and the upper flitch at a depth of 1.5 m from the hole collar. Drilled holes were filled with chippings to attain the required depth for installation. After the holes were surveyed, the BMMs were activated by the activator and installed. In wet holes, the BMMs were placed in a rubber mesh with chippings at the bottom to increase their total weight. This enabled the balls to sink to the bottom of the water.

iii. Recording of depth and signal strength: After the installation of the BMMs, their depth from the collar of the hole and range of installation were recorded and stored by the BMM system. This was performed by holding the system over the monitoring hole and levelling it to obtain accurate readings; and

iv. Backfilling of BMM holes: After the above procedures were done, the holes were then backfilled with chippings to the collar of the hole; completely covered and marked.

2.2 Post Blast Procedures

This sub-section evaluates covers all the steps followed in the detection of the installed BMMs and the analysis of the movement and translation of orebodies after blasting. The following were the procedures involved:

i. Location of BMMs: After blasting was done, to be able to monitor the displacement that occurred, the first thing that was done was to locate the installed BMMs. A starting location was found, it was best to make reference to the blast plan since it contained the various BMMs colour used and their installed location. The detector was switched on and the detection of installed BMMs was started on a higher range to finds peak signal. The detector beeped and displayed graphic highs and lows when it sensed an installed BMM ball nearby. As the detector got closer to the vicinity of the BMM, the beeping got louder with an increase in the highs of the graph on the display detector. In order to validate readings after location of the various BMMs, the signal was checked in all directions by swinging the detector to the right, left, front and back side from the exact position where the detection was made. The signals increased in each direction away from the point of location.

ii. Survey BMM location: After all the BMMs were detected, validated and recorded, the positions of detection were marked by the use of a marker spray and the coordinates of those positions were picked up by the surveyors to be processed using the BMM Explorer software in order to know the exact degree of displacement of the orebody.

The BMM Explorer software was provided with all the details of the blast which are as follows: Blast identification, blast date (dd/mm/yy), hole diameter (mm), bench height (m), spacing and burden (m), delay timing (ms), powder factor (kg/m^3), type of explosive, type of initiation, rock type, hole depth (m), and stemming length (m).

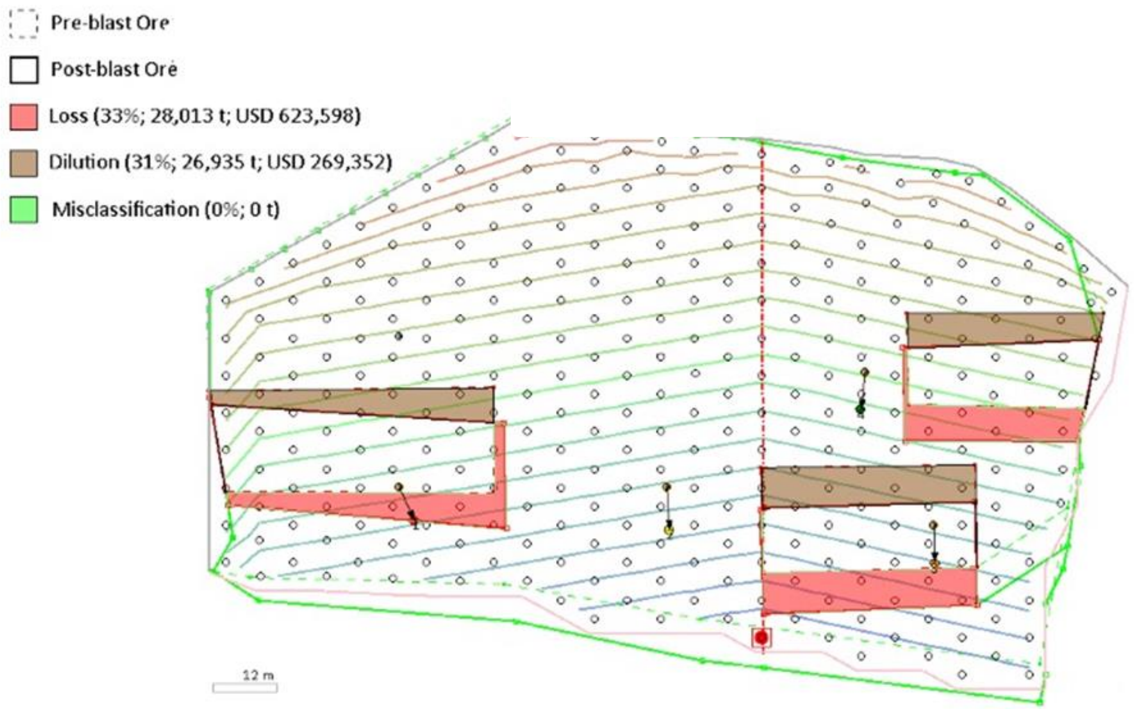

Fig. 2 Percentage of Ore Dilution and Ore Loss of Various Blocks Relative to the Positions of the Pre-Blast Ore [10]

Ore mark out involved the process of demarcating the various ore zones after the orebodies have been displaced by blasting. Surveyors pegged the contacts of the orebodies by considering the new location (coordinates) of the blast monitoring balls' point after blast, after which flagging tapes were used to delineate the various ore zones. Blasting usually covered a depth of 6 m. Coordinates forming the corners of the waste with reference to the block model plan were determined. After ore mark out, the excavation of blasted material to the various destinations followed. Fig. 2 shows an actual block translation before and after blast, potentially 28 013 t and 26 935 t of ore are loss and diluted respectively.

Ore spotting on the other hand involved the process of directing the excavator operator to mine selectively thus to dig ore and waste materials separately to prevent them which may lead to ore losses or ore dilution and also ensuring the appropriate destinations of the materials mined. Communication with the excavator operators was done using Motorola radio and other signals understood by the operators. The operators were communicated to dig at correct angles to prevent the mixing of ore with waste. Also records of the cycle time of the various dump trucks transporting the material from the pit to the various destination were taken. It was ensured that the appropriate flags which symbolised the type of material being mined were put in place. The signage representing the material type mined was placed in front of the dump truck corresponding with the material being fed into it. Basically, it was a good practice mining from the hanging wall towards the footwall. Conventionally at Nzema Gold Mine, red denotes ore of high grade, yellow for low grade, lemon green for marginal grade and blue for waste (Table 1).

Table 1 Grade and Colour Categorisation at Nzema Gold Mine (Adamus Pit)

GRADE	RANGE(m)	COLOUR
Waste	<0.49	Blue
Marginal Grade	0.5-0.69	Lemon Green
Low Grade	0.7-0.79	Yellow
Low Rom	0.8-1.499	Red
High Rom	>1.50	Cornflower

3. Results and Discussion

From the field work performed at the Adamus Pit, three blasts were monitored. A total of 15 BMM balls were installed with all balls recovered after the blasts. A summary of the data from these three blasts and their graphical presentations are shown in Tables 2-4 and Figs. 3-7 respectively.

From the data acquired on the monitoring of blast shot of the three-blast monitored, various graphs were plotted for them. It can be seen that 946_shot_20 (Table 2), had an average 3D displacement of 2.773 m to the west of the original position of the ore blocks and if this was not known, it would have been mined as waste there by contributing to ore loss and ore dilution for that particular ore block. A clear understanding of this can be seen from Fig. 3 which shows the movement of the various ore blocks in the blast panel after blast.

In 952_shot_17 (Table 3), there was an average 3D displacement of 3.593 m to the west of the original position of the ore blocks as shown in Fig. 4. An increase in the displacement value indicates a lesser resistance to the explosives offered by the rock available at that location. There was an interbedding of greywacke and phyllite which made it less resistant to the explosives compared to that of the more competent greywacke rocks of 946_shot_20 (Table 2). The average displacement measured allowed for the correct mining of waste and ore to prevent dilution.

Table 2 Summary of Blast Data from 946_shot_20

Blast Name	946_shot_20								
Date	02/05/2020								
BMM Serial	Collar East	Collar North	Instant Depth	After East	After North	3D Distance	Horizontal Distance	Vertical Distance	Heave
1-R	575366.598	550865.15	4	575364.78	550864.74	1.96288	1.864543	0.6135	2.804
2-Y	575366.598	550865.15	1.6	575366.11	550864.59	1.92606	0.74618	1.7756	2.527
3-G	575371.582	550881.96	4.6	575367.95	550881.55	3.66311	3.655458	0.2366	2.288
4-O	575371.582	550881.96	1.6	575369.67	550881.66	2.80906	1.932647	2.0385	2.463
5-Y	575351.734	550894.06	3	575348.24	550894.16	3.50537	3.498624	0.2174	0.613

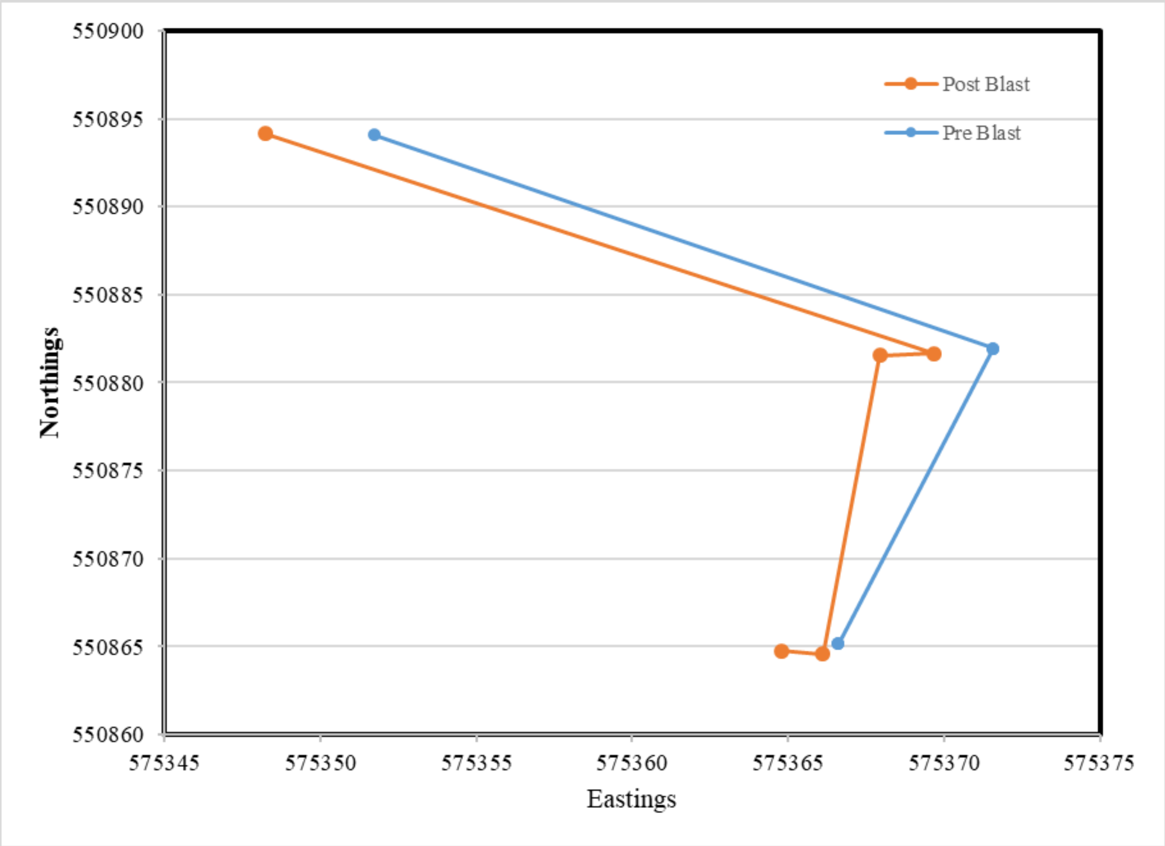

Fig. 3 The Positions of the BMMs for 946_shot_20 Pre and Post Blast

Table 3 Summary of Blast Data from 952_shot_17

Blast Name	952_shot_17								
Date	16/05/2020								
BMM Serial	Collar East	Collar North	Instant Depth	After East	After North	3D Distance	Horizontal Distance	Vertical Distance	Heave
1-R	575458.1424	550862.3668	4.4	575454.008	550863.51	4.29381	4.28954	0.19151	2.222
2-Y	575458.1424	550862.3668	1.5	575454.606	550862.884	4.02726	3.57402	1.85613	2.284

3-G	575455.4452	550885.986	4.5	575451.75	550885.403	4.62914	3.74091	-2.72663	0.134
4-O	575455.4452	550885.986	1.5	575454.641	550885.386	1.25681	1.00336	-0.75686	0.267

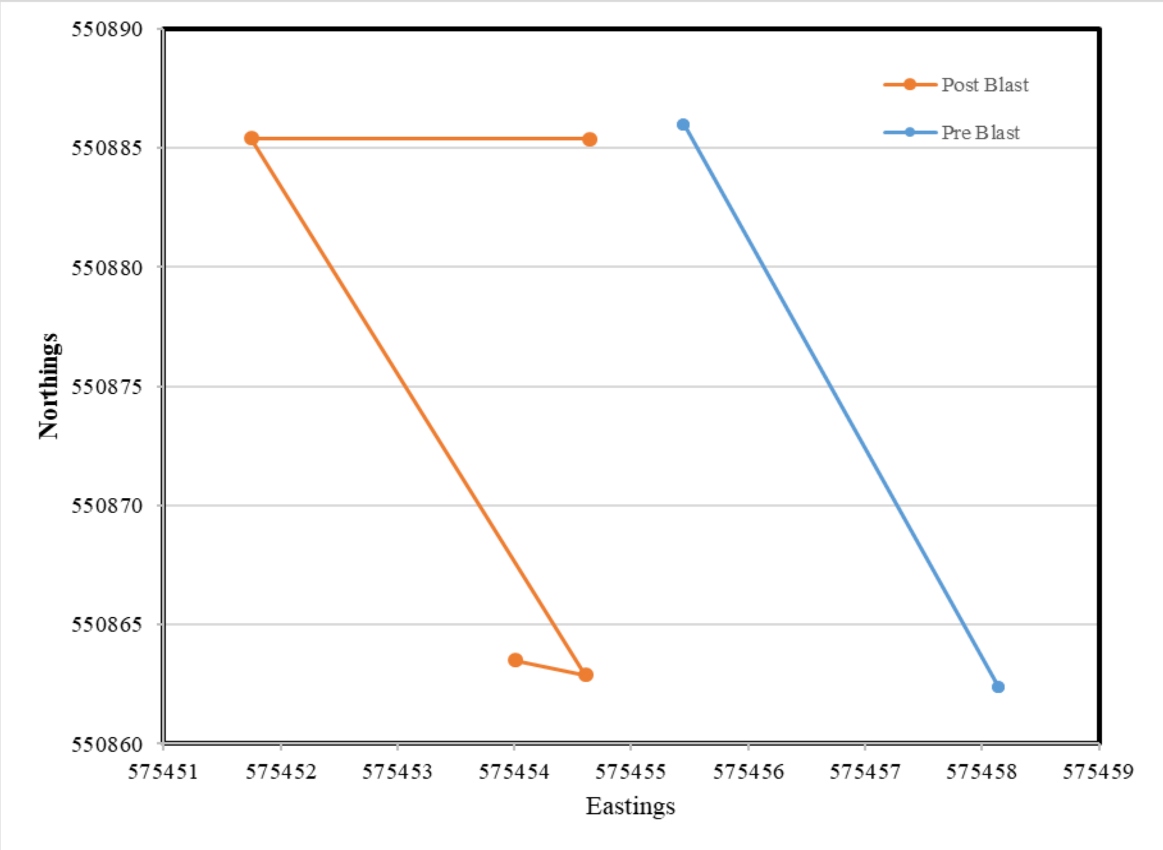

Fig. 4 Graph Showing the Positions of the BMMs for 952_shot_17 Pre and Post Blas

For 952_shot_19 (Table 4), there was an average 3D displacement of 3.556 m of the original position of the ore blocks. This shows the ore blocks shifted averagely by 3.556; to know the actual positions of the ore blocks, there is the need to re-adjust the original positions of the ore blocks by that degree of distance to prevent the digging of waste as ore and vice versa leading to the prevention of dilution.

A graph was drawn using the horizontal displacements for 952_shot_19 (Table 4) bottom flitch and top flitch. It was observed that, the bottom flitch moved farther than the top flitch. The average horizontal movement for bottom and top flitches were 4.11 m and 3.06 m respectively (Fig. 6).

Table 4 Summary of Blast Data from 952_shot_19

Blast Name	952_shot_19								
Date	07/05/2020								
BMM Serial	Collar East	Collar North	Instant Depth	After East	After North	3D Distance	Horizontal Distance	Vertical Distance	Heave
1-R	575434.124	550882.23	4.5	575430	550883.98	4.49223	4.474729	0.3961	-0.25
2-Y	575434.124	550882.23	1.5	575431.68	550884.85	3.65415	3.577088	-0.7465	-1.12
3-G	575428.743	550909.88	4	575425.7	550911.27	3.44214	3.349026	0.7952	2.608
4-O	575428.743	550909.88	1.5	575426.68	550911.18	2.7491	2.438126	1.2701	2.514
5-R	575419.553	550914.63	4.5	575415.51	550915.92	4.44227	4.245888	1.3062	1.708
6-Y	575419.553	550914.63	1.5	575417.12	550915.51	2.76945	2.585835	0.9916	1.581

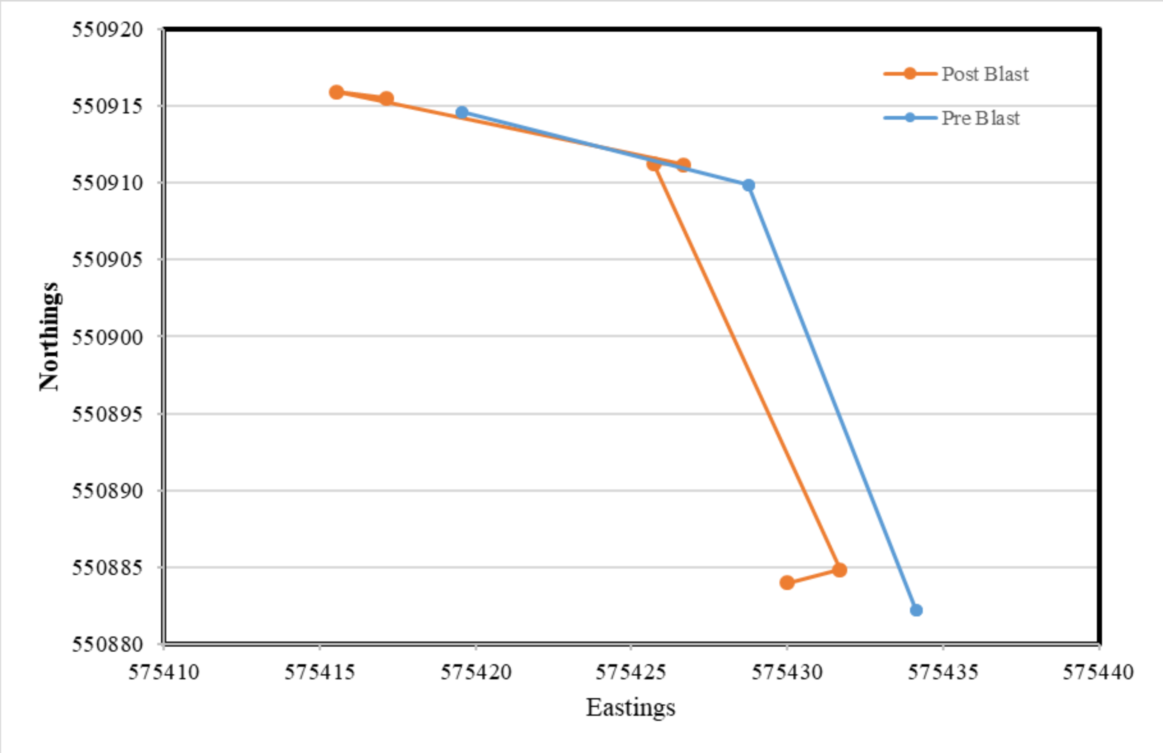

Fig. 5 Graph Showing the Positions of the BMMs for 952_shot_19 Pre and Post Blast

The exercise was carried out for the vertical movement. It should be noted that the heave or vertical movement was calculated from the top of the bench i.e., for 952_shot_19 (Table 4), the top of the bench was 952 RL, hence material above 952 RL was classified as a heave. It could be observed that the top flitch moved higher than the bottom flitch. The average vertical movement for top and bottom flitches were 1.0 m and 0.83 m respectively (Fig7).

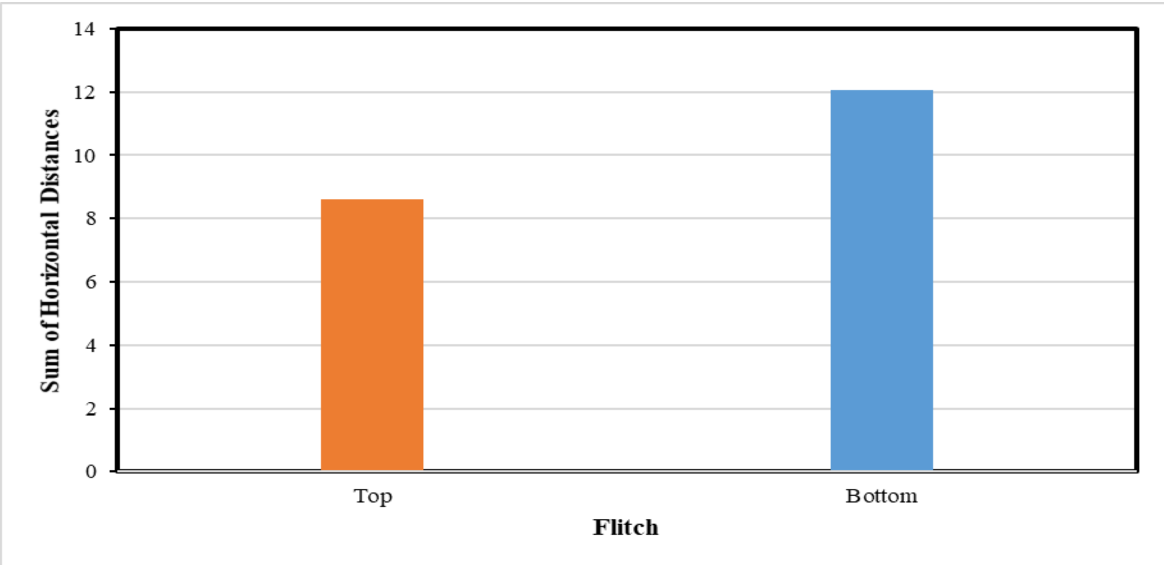

Fig. 6 Graph of Horizontal Movement Interpretation for 952_shot_19 Top and Bottom Flitch

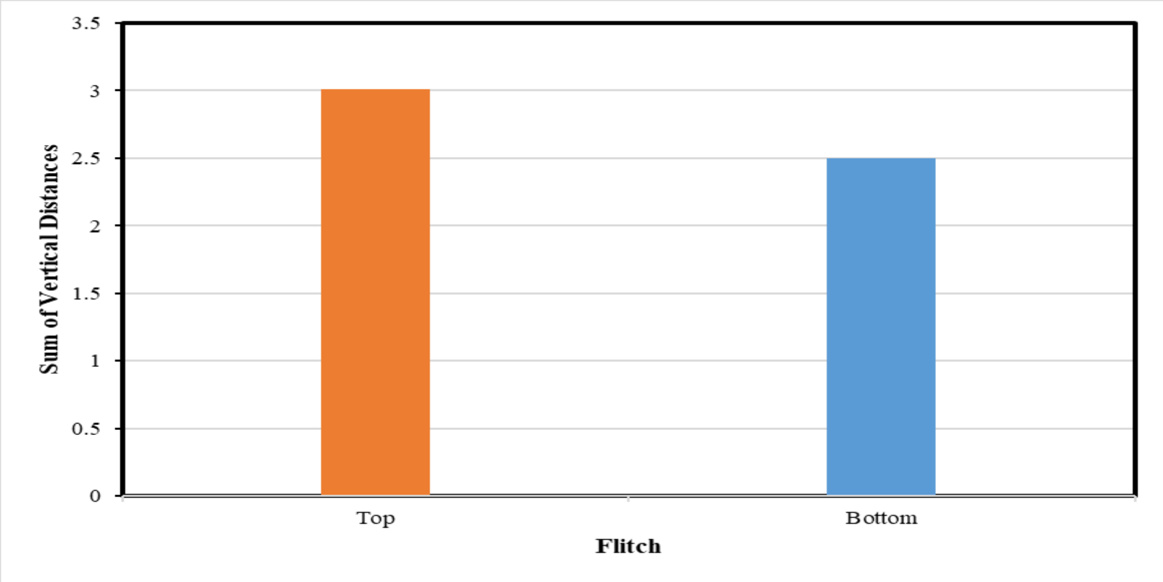

Fig. 7 Graph of Vertical Movement Interpretation for 952_shot_19 Top and Bottom Flitch

From the field activities performed, the following observations concerning ore dilution and ore loss were made. Excessive back break occurs when the orebody to be blasted lies in between weak waste rock zones. These weak waste rocks are affected to some degree by the blast and end up breaking and diluting the ore. Excessive flyrocks occur when rocks travel far across the blast panel after blasting. The flyrock causes the movement of rock from one block to another causing the dilution of the ore block corroborating with [11;12] for similar conditions. Wrong destination of mined material; transporting waste materials to the ROM pad and ROM material to waste dump can lead to ore dilution and ore loss. Trucks may spill waste on the ore as it moves on it, and this can also lead to ore dilution. Inaccurate sorting occurs when the digger operators are not accurately directed to dig the right material and also digging beyond the contacts of the orebody. Wrong ore mark out can lead to ore dilution. Less knowledge about the lithology and structures present may lead to improper delineation of the ore from waste thereby causing ore dilution.

The epitome of the analysis, therefore, is to find out the probable causes of ore loss and ore dilution at the mine, propose possible answers to these operational problems and evaluate the effects of blast induced movement on ore blocks with the use of Blast Movement Technology (BMT). Information was collected on BMM of the mine for examination, and it was observed that, the lowest flitch of the blasted material moved more than the topmost flitch in the horizontal direction while the opposite was the case for the vertical movement. Controlling ore loss, dilution and misclassification is indispensable for all modern mining operations. Ore movement takes place in all blasts, and the inability to account for post-blast movement results in ore sent to the waste pile and waste rock to the processing plant.

4. Conclusion and Recommendations

The following conclusions are drawn:

i. The lesser the resistance of the explosives to the host rock, the higher the displacement of the rocks and vice versa. Comparatively, 946_shot_20 (Table 4.2) gave a 3D displacement of 2.773 m and 952_shot_17 (Table 4.3) gave 3.593 m indicating a more competent host rock at 946_shot_20 (Table 4.2).

ii. The average horizontal displacement of blast monitored at Adamus Pit is such that the bottom flitch of the blasts moved farther than the top flitch; and
iii. The average vertical displacement of blast monitored at Adamus Pit is such that the top flitch of the blasts moved farther than the bottom flitch.

The following recommendations are made:
i. Implementation of the BMT at Adamus Resources Limited, Nzema Mine should be continued and if possible, every shot containing ore should be monitored; and
ii. The use of BMT should be properly supervised to prevent improper installation of the balls. BMT should be adopted by sister mining companies since it accurately monitors blast and affects production economically.

References

[1] D. Thornton, (2009a). The Implications of Blast Induced Movement to Grade Control. Proceedings of the Seventh International Mining Geology Conference, Perth WA, Australia, pp. 287-300.
[2] D. Thornton (2009b). The Application of Electronic Monitors to Understand Blast Movement Dynamics and Improve Blast Designs", Proceedings of the Ninth International Symposium on Rock Fragmentation by Blasting – Fragblast 9, (ed: J A Sanchidrian), pp. 287-399.
[3] J, Loeb. (2017). Minimizing Mining Dilution, Ore Loss, and Misclassification by Accounting for Blast Movement in South American Porphyry-Skarn and Manto Copper Proceedings of PERUMIN 33 Mining correction, Sept 18-22, Lima Peru
[4] Watson M.E, (2017). Blast movement monitors or poly pipe. A case study of cost effective blast monitoring at White Foil gold mine, Western Australia. 10th International Mining Geology Conference, Hobart, Tasmania, 20-22 September. Case Studies. https://blastmovement.com/the-bmt-solution/case-studies/ [13/03/22]
[5] T. N. Little and F. Van Rooyen (1988). The Current State of the Art of Grade Control Blasting in the Eastern Goldfields. The AusIMM Explosives in Mining Workshop, Melbourne, Victoria, pp. 87-95.
[6] D. La Rosa, and D. Thornton (2011). Blast Movement Modelling and Measurement. Proceedings of the 35th APCOM Symposium, Wollongong, pp. 78-112.
[7] Anon. (2013). Regional Map of Nzema Gold Mine", http://endeavourmining.com. [Accessed: 25th June 2021.]
[8] R. J Yeast and R. I. Hyde. (2004). Southern Ashanti Gold Project. Unpublished Technical Report, Adamus Resources Limited, 107 pp.
[9] [13] G. H. Cameron (2008). Report on the Geology and Control on the Mineralisation at the Salman Gold Deposit. Technical Report Unpublished, Adamus Resources, Western Australia, 178 pp.
[10] J. Loeb and D. Thornton (2014). A Cost Benefit Analysis to Explore the Optimal Number of Blast Movement Monitoring Locations. Proceedings of the Ninth International Mining Geology Conference, Adelaide, 34 pp.
[11] E.K Amosah. (2021). Control of Ore Loss and Ore Dilution at Adamus Resources Limited, Nzema Mine Using Blast Movement Technology-Blast Induced Movement and Its Effects on Grade Dilution at the Coeur Rochester Mine. BSs Project, Department of Mining Engineering, University Mines and Technology, Tarkwa, Ghana 38 pp.
[12] P. A. Eshun, and K. A. Dzigbordi, (2016). Control of Ore Loss and Dilution at AngloGold Ashanti, Iduapriem Mine using Blast Movement Monitoring System. Ghana Mining Journal, Vol. 16, No. 1, pp. 49 - 59.