ISBN 4-9902356-6-5

Department of Earth Resources Engineering
Kyushu University
Fukuoka, Japan

The Institute of Economics and Control Systems
Faculty of Mining and Geology, VŠB - Technical University of Ostrava
Ostrava, Czech Republic

Faculty of Earth Sciences and Material Technology, ITB
Bandung, Indonesia

Mining and Materials Processing Institute, Japan (MMIJ)

Proceedings of

3rd International Workshop on Earth Science and Technology

Sponsored by
Faculty of Engineering, Kyushu University,
Kyushu University Foundation,
MMIJ-Kyushu Blanch,
and MMIJ-Division of Coal Mining Technology

FUKUOKA DECEMBER 2005

CONTENTS

STOPING-INDUCED DISPLACEMENTS IN A FRACTURED VEIN AT PONGKOR UNDERGROUND GOLD MINE, INDONESIA

Barlian DWINAGARA, Budi SULISTIANTO, Ridho. K. WATTIMENA [1]

Suseno KRAMADIBRATA, M. Safrudin SULAIMAN [1]

Kikuo MATSUI [2]

Iwan Dharma SETIAWAN [3]

[1] Department of Mining Engineering

Faculty of Earth Science and Mineral Technology

Institute of Technology Bandung, Bandung 40132, Indonesia

E-mail : barlian@mining.itb.ac.id

[2] Kyushu University Fukuoka 812-8581, Japan

[3] Gold Mining Business Unit of Pongkor, PT. ANTAM, Tbk., Indonesia

ABSTRACT

The cut and fill method is applied at Pongkor underground gold mine where a number of level is mined simultaneously. To ensure that mining in each level can be carried out safely, sill pillars must be left at the top of each level, which thickness must be carefully determined. For the purpose of determination of the thickness, displacements in the vein must be understood.

INTRODUCTION

Considering the general characteristics of rock and ore, a full mechanised cut and fill method is adopted at Ciurug vein, Pongkor Underground Mine. More than one level is opened in order to maintain the continuity of total rate and grade of ore production, i.e level 500, level 600, and level 700. Consequently, sill pillars should be left immediately below the upper level.

Stability of the pillar is absolutely required for ensuring the safety of people and mining equipment. The pillar is the part of vein that is left. This naturally contains fractures and cracks that are induced by blasting. Measurement of displacement at the vein is therefore of importance to observe stoping-induced deformation.

A representation of ore body at cross-cut 6A located at elevation 568 was chosen for the measurement. This research is a continuation of the former research conducted in the neighbouring area (Sulistianto, et al, 2003a, 2004).

DISPLACEMENT MEASUREMENT

Extensometer

Measurement station was located at XC 6A in Level 500 of Block II Central Ciurug, at an elevation of 568 m, about 3.100 m from the portal and around 300 m from the surface. Boreholes for the placing the extensometer magnetic anchors ($T_0 - T_4$) were oriented horizontally and vertically into the vein (Au-Ag ore), as illustrated in Figure 1. The equipment used was *Intrinsically Safe Magnesonic Probe Extensometer* of Type 1062.

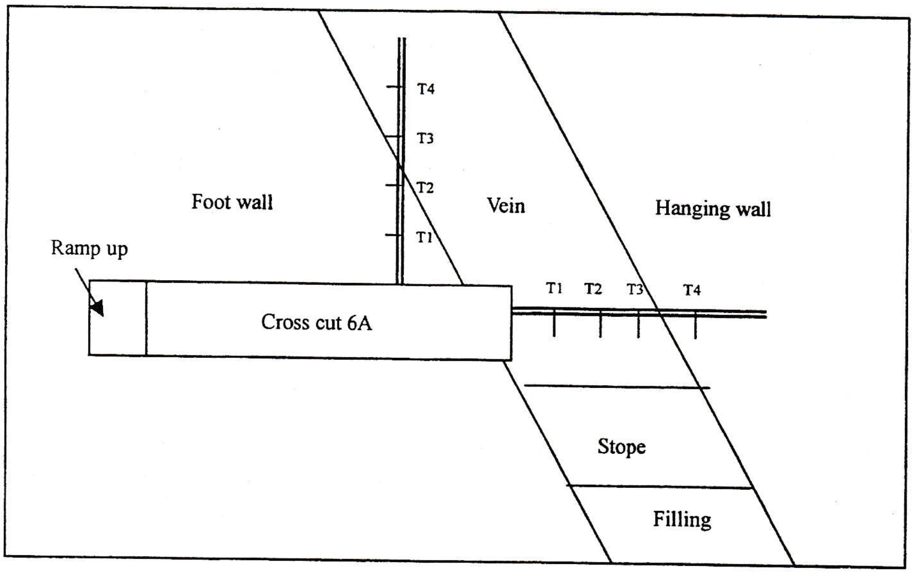


Figure 1. Magnetic anchors in borehole

When installing the extensometer, it was guaranteed that the anchors were placed in a certain depth such that they were not affected by operational activities in the tunnel and solely influenced by the rock mass movement. The change in distance between the first (reference) anchor and the last (deepest) anchor therefore represented the total movement of rock mass that could be detected. The absolute movements between other anchors (T_1, T_2, T_3, and T_4) were calculated by assuming that the first or last anchors (T_1 or T_4) did not move. For an example, $T_{4\text{-}3}$ represents displacements between T_4 and T_3 where T_4 does not move. The displacement calculation was based on the change of distance between the two magnetic anchors as follows:

$$\Delta L = L_t - L_0 \qquad (1)$$

Where:
ΔL = distance change (displacement), mm
L_t = final distance at time t, mm
L_0 = initial distance, mm

The measurement was conducted everyday to find the response of the vein to the mining operations in the stope located below. The initial positions of the magnetic anchors are listed in Table 1. During the measurement, mining in the below stope (accessed trough XC 5A) was being conducted. The mining had progressed to third slice leaving a vertical distance of 3 m, from the XC 6A floor to the stope roof. At the beginning of the measurement, the stope was 63 m (horizontal) from the station. The mining then moved towards the station (distance of 0 m) and then passed the station.

Table 1. Initial positions of magnetic anchors from the collars

Anchor	Top Borehole		Front Borehole	
	Position	Rock	Position	Rock
T_1	1123 mm	Foot wall	1146 mm	Vein
T_2	2411 mm	Foot wall	2365 mm	Vein
T_3	3892 mm	Vein	3867 mm	Vein
T_4	5883 mm	Vein	5887 mm	Hanging wall

is depicting the accumulative displacements as the stoping move forward to the station and passed the station ven in Figure 2 for top borehole and Figure 3 for front borehole,

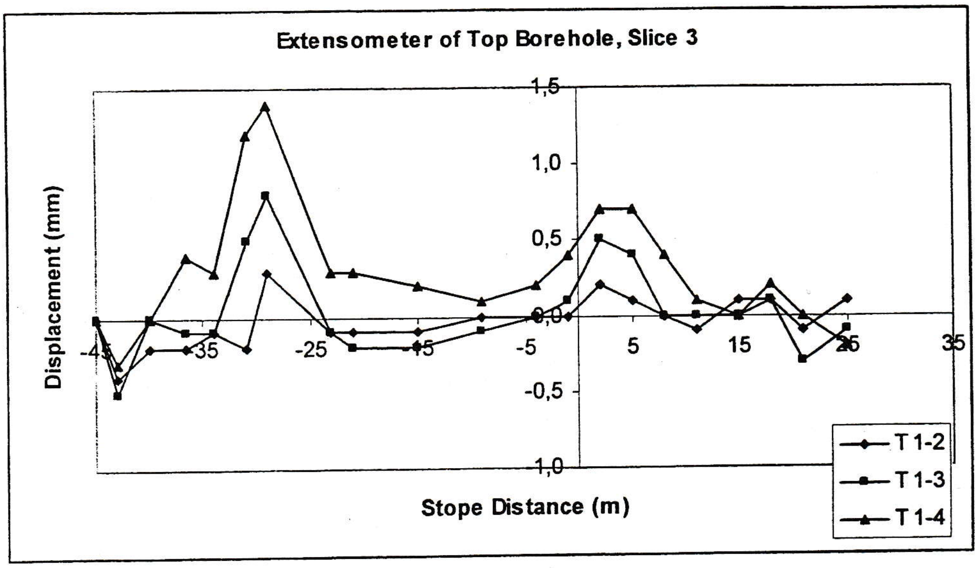


Figure 2. Accumulative displacement along top borehole

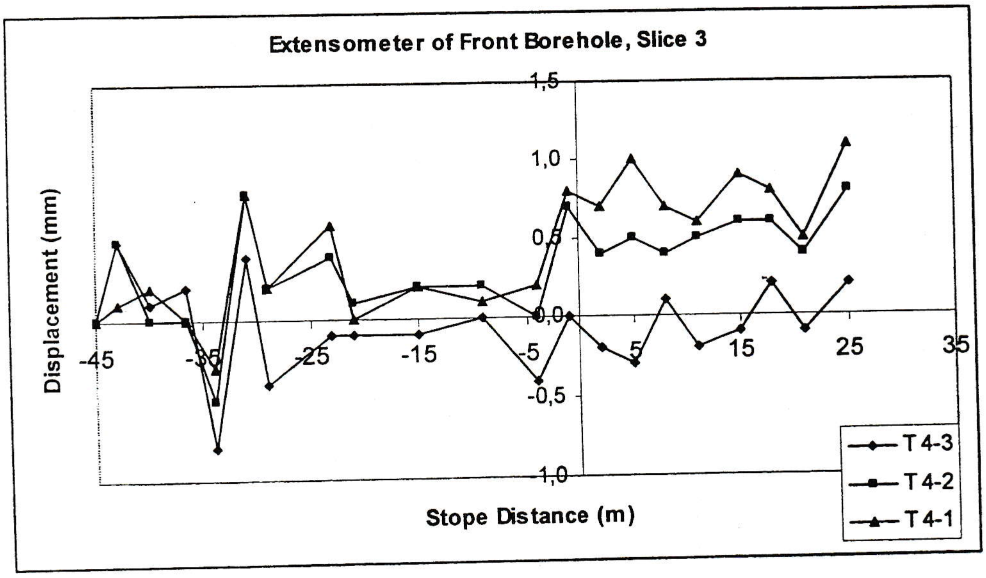
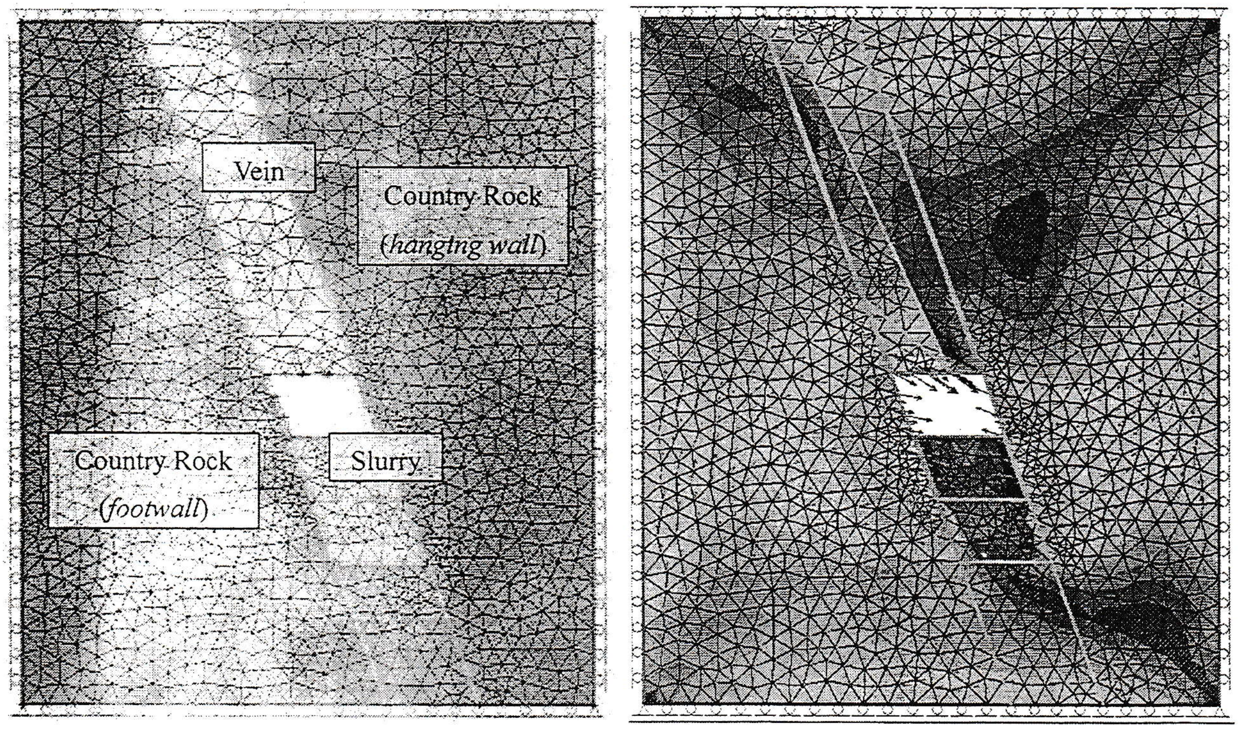


Figure 3. Accumulative displacement along front borehole

Numerical Modelling

Numerical modelling was carried out using Finite Element Method. The input data were stope geometry, mining sequences, discontinuities, rock mass properties, and in situ stresses in the measurement location. The analysis was then focused on the displacements occurred in the points represented the magnetic anchors positions.

In the model the stope was approximately 5 m wide and the thickness of mining slice was 3 m. Calculation was performed for each slicing, where slurry backfill was placed at the end of each slicing. Rock mass properties were taken from the laboratory with an adjustment factor of 75% applied to the Young's Modulus. The in situ stresses were 4.226 MPa for $\sigma1$ and 0.385 MPa for $\sigma3$ (Sulistanto, et.al, 2003b). Discontinuities were based on borehole camera observations (Figures 6 and 7) and cores from the front borehole (Figure 8). The FEM model and the calculation result are given in Figure 4. The numerical model revealed that the rock mass, in particular the vein located in the front and in the top of the XC 6A, moves downward in the direction of vein dip.



(a) (b)

Figure 4. FEM Modelling: (a) Model, (b) Result

Displacement Comparison between Extensometer Measurement and FEM Modelling

In the movement calculation it was assumed that the vein moved downward due to the mining operations carried out in the stope located below. It was therefore supposed that the fixed anchors for the top and front extensometers were T1 in the footwall and T4 in the hanging wall respectively. The last measurement was carried out when the mining passed the station. The comparison between displacement measured using extensometer and that predicted by the FEM modelling is given in Table 2.

Table 2. Displacements at the end of measurement

Slice	Instrument	Displacement (mm)					
		Top borehole			Front borehole		
		T_{1-2}	T_{1-3}	T_{1-4}	T_{4-3}	T_{4-2}	T_{4-1}
3	Extensometer	0,1	-0,1	-0,2	0,2	0,6	0,9
	Model	-0,1	-0,1	-0,1	0,1	0,4	0,5

IN CONDITION AND BOREHOLE CAMERA

: directions of fractures within the rock mass are parallel to the vein dip, as shown in Figure 5, which was taken de the stope. This condition might cause downward movement of the vein. The fractures have also been erved by a borehole camere inserted in the front borehole.

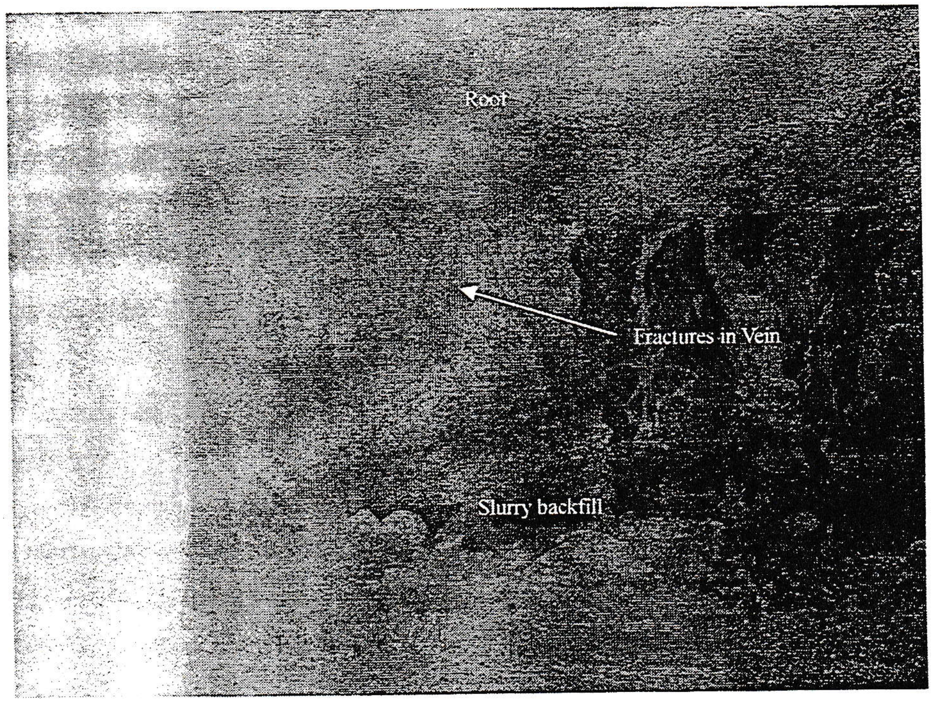


Figure 5. Fractures in vein

lased on information obtained from the borehole, more detailed inspections have been conducted at the depth of 40 cm and 265 cm in the front borehole. The borehole camera still images show that there were continuous liscontinuities which directions (strike/dip) were N338^{0}E/40^0 at the depth of 140 cm and N356^{0}E/65^0 at the depth of 265 cm (Taufik, 2005), as shown in Figures 6 and 7. The strike/dip of the discontinuities were similar to the general direction of fractures in the vein measured directly inside the stope, which was N357^{0}E/84^0.

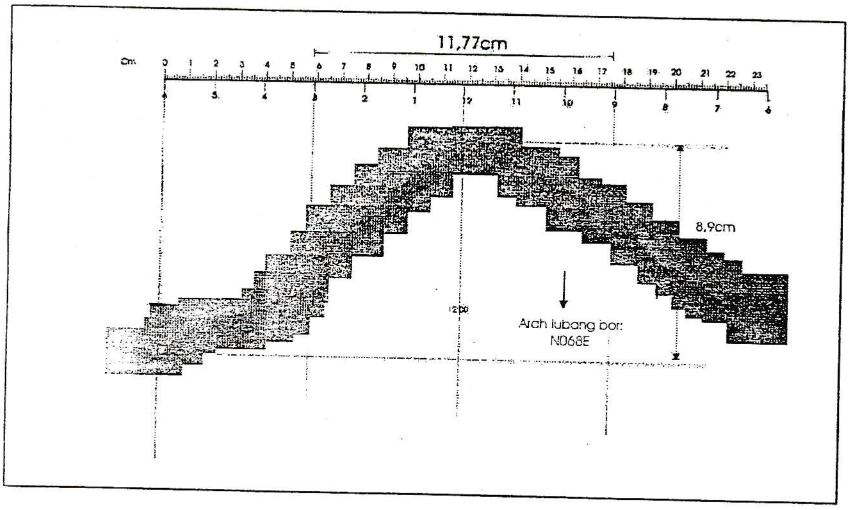


Figure 6. Crack at the depth of 140 cm

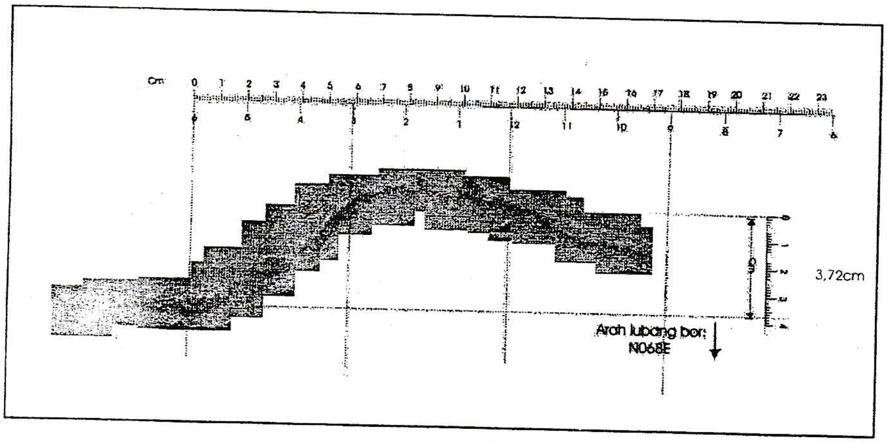


Figure 7. Crack at the depth of 265 cm

The drill cores up to a depth of 15 cm was crushed, which showed that contact between vein and footwall was a crushed zone. In addition, discontinuities were also clearly observed at the depths of 140 cm and 265 cm, which confirmed the borehole camera images. The front borehole core box photo is given in Figure 8.

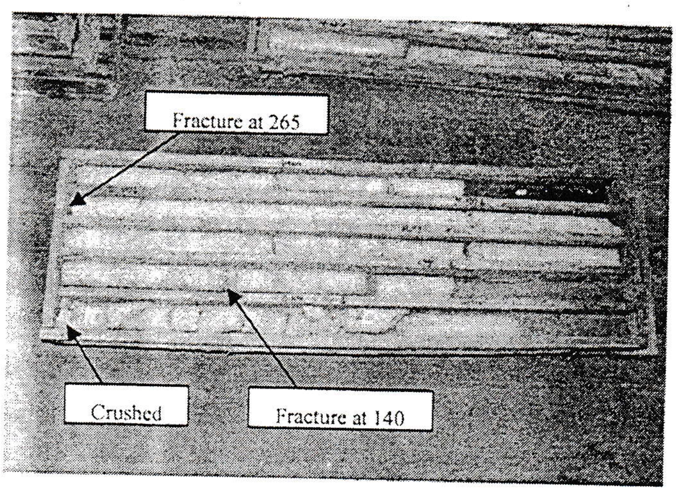


Figure 8. Core box of front borehole

DISCUSSION

Displacements from extensometer measurement and numerical model both showed negative value at the top borehole and positive value at the front borehole. The only difference was magnetic anchor T_{1-2} in top borehole, where the extensometer gave a positive value, whereas the numerical model gave a negative value. The magnitude of both displacements was relatively similar. The negative value at the top borehole was related to the shortening of distance between anchors which indicated a downward movement. The positive value at the front borehole was associated with a downward movement toward the footwall, indicated by a lengthening of distance between anchors. It can be then thought that stoping conducted below caused a downward movement of the vein which direction was parallel to the dip of the vein. Furthermore, the discontinuities in the vein and the contact between vein and the footwall also contributed to the movement.

As the measurement was conducted in the elevation of 568 m, the results must therefore be taken into account in the calculation of the Factor of Safety of the sill pillar, which will be located in the elevation of 590 m.

CONCLUSION

Having investigated the displacement provided by extensometer measurement and that given by numerical modelling, it can be concluded that the vein experienced downward movement in the direction of its dip, caused by stoping activities conducted underneath the measurement station.

ACKNOWLEDGEMENT

The authors thank the Pongkor Gold Mining Business Unit of PT. Antam, Tbk. for all supports for this tripartite research. Mr Slamet Prambudi who carried out the analytical calculation also deserves special thanks.

REFERENCES

Sulistianto, B.., Dwinagara, B., Rai, M.A., Kramadibrata, S., Matsui, K., Nakagawa, H., Setiawan, I.D., Janu, E. & Risono, 2003, *The displacement monitoring at Ciurug Southern Ramp-up of Pongkor underground gold mine, West Java, Indonesia*; Proceedings of International Workshop on Earth Science and Technology, Fukuoka, Japan, November 7th, 2003a: 49 – 54.

Sulistianto, B., Rai, M.A., Kramadibrata, S., Hartami, P.N., Matsui, K., Nakagawa, H., Setiawan, I.D., Janu, E. & Risono, 2003b, *Determination of insitu stress using hydraulic fracturing method at Pongkor underground gold mine, West Java, Indonesia*; Proceedings of The Third International Symposium on Rock Stress, RS Kumamoto, 4-6 November 2003, Kumamoto, Japan, Edited by Sugawara, K., Obara, Y., Sato; A : 383-388., AA. Balkema Publishers, Tokyo.

Sulistianto, B., Wattimena, R.K., Kramadibrata, S., Rai, M.A., Dwinagara, B., Matsui, K., Setiawan, I.D., Sudarman, H., Herlambang, E.J., *Influence of stope on drift displacements in a fractured rock mass at pongkor undergorund gold mine, Indonesia*; Proceedings of The ISRM International Symposium: Third Asian Rock Mechanics Symposium, Kyoto, Japan, November 30 – December 2, 2004: 485 – 488.

Taufik, R., *Penggunaan Borehole Camera pada Pengamatan Pergerakan di Lubang Bor No.8, Urat Ciurug, Pongkor*, Thesis of Undergraduate Programme, Department of Mining Engineering, Faculty of Earth Science and Mineral Technology, Institute of Bandung Technology, 2005: IV.7 – IV.12.