



Department of Earth Resources Engineering  
Kyushu University  
Fukuoka, Japan

*M. Ito*  
5/12/05

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

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## CONTENTS

GEOTHERMAL SYSTEM OF GUNTUR VOLCANO WEST JAVA – INDONESIA A PRELIMINARY INTEGRATED STUDY USING ASTER IMAGE, MAGNETOTELLURIC, AND 3D TOMOGRAPHIC WITH FIELD RECONNAISSANCE	1
<i>Asep SAEPULOH, SURYANTINI and P. SUMINTADIREJA. A</i>	
GEOTHERMAL FIELDS OF JAVA ISLAND, INDONESIA: THEIR DESCRIPTIONS, GEOLOGIC ENVIRONMENTS, AND PRELIMINARY AREA-SELECTION EXPLORATION STRATEGY	11
<i>SURYANTINI, Lucas D. SETJADJI, Rina WAHYUNINGSIH, Sachio EHARA, Akira IMAI and Koichiro WATANABE</i>	
HYDROTHERMAL SYSTEM OF THE UNGARAN GEOTHERMAL AREA, INDONESIA INFERRED FROM GEOCHEMICAL STUDY	19
<i>Nguyen Kim PHUONG, Heru HENDRAYANA, Agung HARJOKO, Ryuchi ITOI and Rie UNOKI</i>	
GEOTHERMAL GRADIENT STUDY OF ON-SHORE NORTH WEST JAVA BASIN FROM PETROLEUM WELLS	29
<i>SURYANTI and Sachio EHARA</i>	
EFFECTS OF A GREEN TUFF ON ACTIVATING MICROORGANISMS	41
<i>Yuichi SUGAI and Kyuro SASAKI</i>	
ESTIMATION OF METHANE GAS EMISSION INTO UNDERGROUND COAL MINES IN QUANG NINH COALFIELD, VIETNAM	47
<i>Phung Quoc HUY, Tran Tu BA and Pham Chan CHINH</i>	
GAS PRODUCTION SYSTEM FROM METHANE HYDRATE LAYER BY HOT WATER INJECTION USING DUAL-HORIZONTAL WELLS	55
<i>Shinji ONO, Yuichi SUGAI, Kyuro SASAKI, Takao EBINUMA, Tsutomu YAMAGUCHI and Hideo NARITA</i>	
A STUDY ON HEATING AND COOLING PHENOMENON OF AIR IN CIURUG PONGKOR GOLD MINE LEVEL 515	63
<i>Nuhindro Priagung WIDODO, Masahiro INOUE, RISONO, Rudy Sayoga GAUTAMA and BUDIANTO</i>	
RECOVERY OF URANIUM USING MICROORGANISMS ISOLATED FROM URANIUM DEPOSITS	69
<i>Takehiko TSURUTA</i>	
STUDY ON RECYCLING OF DEHYDRATION CAKE PRODUCED FROM CRUSHED ROCK QUARRIES	81
<i>Hiroshi TAKAHASHI, Kazuhito YOSHIMOTO and Yuko SUTO</i>	
PHYSICAL SEPARATION PROCESS FOR RECOVERING PHOSPHORUS FROM ANAEROBIC DIGESTED SLUDGE	89
<i>Takao HAGINO and Tsuyoshi HIRAJIMA</i>	

JOINT USE OF ANALYTIC SIGNAL, SECOND VERTICAL DERIVATIVE AND TRANSFORMATION FILTER FOR 2D AND 3D GRAVITY DATA INTERPRETATION	97
<i>Hakim SAIBI, Jun NISHIJIMA and Sachio EHARA</i>	
NUMERICAL SIMULATION OF GROUND HEAT EXCHANGER ON AN ABANDONED DEEP WELL USING AUTOUGH2	105
<i>Sandy Kurniawan SUHARDJA, Ryuichi ITOI and Fujii HIKARI</i>	
BEHAVIOR OF CHLORINE IN MUNICIPAL SOLID WASTE INCINERATOR RESIDUES MIXED WITH ORGANIC MATTERS -AN EXPERIMENTAL APPROCH TOWERDS RECYCLED MATERIAL FOR CEMENT-	113
<i>Jiro ETOH, Tomonori TAKEMOTO, Hisao YAMASHIGE, Haixia ZHANG, Jung-Joon LEE and Takayuki SHIMAOKA</i>	
DETERMINATION OF GOLD CONTENT IN SEDIMENTARY ROCKS AROUND THE HISHIKARI GOLD DEPOSIT, JAPAN	119
<i>Kenzo SANEMATSU, Tetsuya NAKANISHI, Akira IMAI and Koichiro WATANABE</i>	
DURABILITY CHARACTERISTICS OF SUBANG CLAYSTONE IN RELATION TO THE GENERATION OF SHALLOW LANDSLIDES	125
<i>Imam A. SADISUN, Hideki SHIMADA, Masatomo ICHINOSE and Kikuo MATSUI</i>	
INSOLUBILITY OF LEAD IN INCINERATED ASH ARISING FROM CARBONATION	133
<i>Takashi HARAGUCHI, Takayuki SHIMAOKA, Koichiro WATANABE, Jiro ETOH, Ruina ZHANG and Takeshi KAWAGOE</i>	
CONVERGENCE MONITORING AND DAMAGE MAPPING FOR ASSESSING THE STABILITY OF EXTRACTION LEVEL IN DOZ UNDERGROUND MINE, PT FREEPORT INDONESIA	139
<i>Ridho Kresna WATTIMENA, Eman WIDIJANTO and Husni SAHUPALA</i>	
ROLE OF MAGNESIUM FOR THE FORMATION OF SMECTITE PRECIPITATED FROM GEOTHERMAL WTER AT GEOTHERMAL POWER PLANT	149
<i>Yoshinobu ARAMAKI, Takushi YOKOYAMA, Yoshihiro OKAUE, Akira IMAI and Koichiro WATANABE</i>	
TEMPORAL VARIATION OF METALS AND ORGANIC MATTER IN A LANDFILL MAINLY DISPOSED WITH MUNICIPAL SOLID WASTE INCINERATION RESIDUES	153
<i>Haixia ZHANG, Takayuki SHIMAOKA, Jung-Jong LEE and Ruina ZHANG</i>	
STUDY ON DEVELOPMENT OF NEUTRAL FIBER SOLIDIFICATION MATERIAL BY USE OF WASTED GYPSUM BOARDS AND ITS APPLICATION TO SOIL IMPROVEMENT	161
<i>Hiroshi TAKAHASHI, Hirofumi AKUZAWA and Masato MORI</i>	
CURING TIME AND STRENGTH IMPROVEMENT OF BACKFILLING MATERIAL TO INCREASE PRODUCTIVITY	171
<i>Budi SULISTIJO, Adriyanto D KUSUMO and Bambang HARIYONO</i>	

STUDY ON RECYCLING OF WASTED SOILS AND PAPER SLUDGE: APPLICATION OF PAPER SLUDGE TO SOIL IMPROVEMENT	177
<i>Hiroshi TAKAHASHI, Masaya DOI, Masato MORI and Yuko SUTO</i>	
STUDY ON ENVIRONMENTAL PRESERVATION TYPE SOIL RESTORATION METHOD TO REDUCE THE MARINE DAMAGE DUE TO OUTFLOW OF RED SOIL	187
<i>Hiroshi TAKAHASHI, H.NAKAMURA, Masato MORI and K.KUMAKURA</i>	
SUCCESSFUL OPERATION OF CONTINUOUS HYDROTHERMAL SYSTEM TO UPGRADE THE LOW RANK COAL AND WOODY BIOMASS MIXTURE	197
<i>Moriyasu NONAKA, Tsuyoshi HIRAJIMA, Ryohei KAKIZOE, Keiko SASAKI, Fujio TSUCHIYA and Masao TSURUI</i>	
OXYGEN REDUCTION BY DECOMPOSITION PROCESS OF MIXED HUMUS-TOPSOIL MULTILAYER PREVENTING PYRITE OXIDATION IN OVERBURDEN DUMPED	203
<i>Lana SARIA and Takayuki SHIMAOKA</i>	
WASTE AND TAILING TREATMENT AT PONGKOR GOLD MINE	213
<i>Ariyanto Budi SANTOSO and MUHIDIN</i>	
APPLICATION OF GIS IN EXPLORATION MANAGEMENT AND WELL SITE SELECTION OF NAMAFJALL GEOTHERMAL AREA, NORTH ICELAND	223
<i>Younes NOOROLLAHI</i>	
GEOLOGY, ALTERATION AND MINERALIZATION IN THE KINGKING PORPHYRY COPPER-GOLD DEPOSIT, COMPOSTELA VALLEY, PHILIPPINES	241
<i>Leilanie O. SUERTE, Sho NISHIHARA, Akira IMAI, Koichiro WATANABE, Graciano P. YUMUL, Jr. and Victor B. MAGLAMBAYAN</i>	
THE HYDROTHERMAL STUDY OF MERAPI VOLCANO, CENTRAL JAVA, INDONESIA	251
<i>Harmoko UDI, Sachio EHARA and Yasuhiro FUJIMITSU</i>	
ENERGY SUPPLY PLAN USING AN ABANDONED DEEP WELL IN HORONOBE, HOKKAIDO, JAPAN	259
<i>Hiroaki OKUBO, Hikari FUJII, Jun MITSUHASHI and Yoji ISHIJIMA</i>	
GEOSTATISTICAL ESTIMATION AND SIMULATION FOR UNCERTAINTY ASSESSMENT OF COAL RESOURCES	267
<i>Mohamad Nur HERIAWAN and Katsuaki KOIKE</i>	
FORMATION POROSITY PREDICTION USING NEURAL NETWORK: CASE STUDY AT A2-VD OIL PROSPECT IN VIETNAM	275
<i>Ho Trong LONG, Bui Thi Thanh HUYEN, Gad EL-QADY and Keisuke USHIJIMA</i>	
INTEGRATED INTERPRETATION OF VES DATA AND MT DATA IN THE SIBAYAK GEOTHERMAL FIELD, INDONESIA	281
<i>Supriyanto SUPARNO, Yunus DAUD, Hideki MIZUNAGA and Keisuke USHIJIMA</i>	

GIS-BASED TWO-DEMENSIONAL NUMERICAL SIMULATION OF DEBRIS FLOW AND HAZARD ASSESSMENT	289
<i>Chunxiang WANG, Tetsuro ESAKI, Yasuhiro MITANI, Mowen XIE and Cheng QIU</i>	
STEEL SLAG GRANULATION	297
<i>Eddy A. BASUKI, Mohammad IRFAN, Djamhur SULE, Arief SUDARSONO, Ismi HANDAYANI, Zaki MUBAROK, MURTIASTANTO, MUSTAQIEM and Edo ANURAGA</i>	
THE CR <sup>6+</sup> -CONTAMINATION POTENTIAL INTO GROUNDWATER IN NI-LATERITE MINE	309
<i>Sudarto NOTOSISWOYO, Harry ASMAR, Kuyung A NAZOM, Totok DARIJANTO, Ariet SUDARSONO, Bahri AMRAN, Irwan ISKANDAR and Agus Haris WIDAYAT</i>	
A NEW CONCEPT OF LINING MATERIAL FOR MUNICIPAL SOLID WASTE LANDFILLS	321
<i>Anel A. ROBERTS and Takayuki SHIMAOKA</i>	
LEACHING OF PLATINUM GROUP METALS FROM AUTOMOTIVE CATALYST RESIDUE BY USING HCL-NACLO-H <sub>2</sub> O <sub>2</sub> SOLUTION	333
<i>Yucai CAO, Sri HARJANTO, Atsushi SHIBAYAMA, Isao NAITOH, Toshiyuki NANAMI, Koichi KASAHARA, Yoshiharu OKUMURA, Kejun LIU, Toyohisa FUJITA</i>	
STOPING-INDUCED DISPLACEMENTS IN A FRACTURED VEIN AT PONGKOR UNDERGROUND GOLD MINE, INDONESIA	341
<i>Barlian DWINAGARA, Budi SULISTIANTO, Ridho. K. WATTIMENA, Suseno KRAMADIBRATA, M. Safrudin SULAIMAN, Kikuo MATSUI and Iwan Dharma SETIAWAN</i>	
PREDICTING TUNNEL CONDITION USING SEISMIC REFRACTION METHOD WITH IN TUNNEL SOURCE SYSTEM	349
<i>Budi SULISTIJO and Hendra FADILLA</i>	
FIELD WORKS ON FRAGMENTATION AND VIBRATION OF BLASTING OPERATION AT A LIMESTONE QUARRY	355
<i>Ganda Marihot SIMANGUNSONG, Hideki SHIMADA, Kikuo MATSUI, Shiro KUBOTA, Yuji WADA and Yuji OGATA</i>	
DEVELOPMENT OF ZIRCON BASE INDUSTRIAL PRODUCT FROM ZIRCON-SAND CONCENTRATE OF BANGKA TIN PROCESSING	365
<i>S. SOEPRIYANTO, A. KORDA and T. HIDAYAT</i>	
COMPUTER PROGRAMS DEVELOPMENT FOR OPERATIVE CONTROL OF TRANSPORT AT DEEP COAL MINES	373
<i>Alois BURÝ</i>	
MODELLING OF MATERIAL SUPPLY AND COAL TRANSPORT IN THE UNDERGROUND COAL MINE	379
<i>Miloš JENDRYŠČÍK and Richard ŠIMEK</i>	

<p>           BIOGENIC MANGANESE OXIDE PRODUCED BY A MN-OXIDIZING PICEA GLAUCA SP -LIKE STRAIN OF FUNGUS, AND ITS ENVIRONMENTAL APPLICATIONS  <i>Keiko SASAKI, Minoru MATSUDA, Tsuyoshi HIRAJIMA, Keishi TAKANO and Hidetaka KONNO</i> </p>	387
<p>           DEVELOPMENT OF RECYCLING TECHNOLOGY FOR MUNICIPAL SOLID WASTE INCINERATION (MSWI) ASH WITH HYDROTHERMAL SYNTHESIS METHOD  <i>Takeshi KAWAGOE, Jiro ETOH, Takayuki SHIMAOKA and Koichiro WATANABE</i> </p>	397
<p>           DEPOSITIONAL FEATURES AND TECTONIC SIGNIFICANCES DURING MESOZOIC PERIOD IN THE KUQA FORELAND BASIN, WESTERN CHINA  <i>Jingchang LI, Koichiro WATANABE and Akira IMAI</i> </p>	405
<p>           ADSORPTION BEHAVIOR OF GOLD(I) AND SILVER(I)-THIOSULFATE COMPLEX ANIONS ON THE SURFACE OF ALUMINA AND SILICA GELS; IMPLICATION TO FORMATION MECHANISM OF LOW-SULFIDATION EPITHERMAL GOLD-SILVER DEPOSITS  <i>Kotaro YONEZU, Takushi YOKOYAMA, Yoshihiro OKAUE, Akira IMAI and Koichiro WATANABE</i> </p>	417
<p>           REMOTELY SENSED SPACE-TIME CHANGES OF SEA ENVIRONMENTS USING REFLECTANCE SPECTRA OF SURFACE MATERIALS  <i>Ayako TAMURA, Takashi NAKATSURU, Katsuaki KOIKE and Fumihiko YAMADA</i> </p>	425
<p>           RECONSTRUCTION OF CENOZOIC VOLCANIC CENTERS IN JAVA ISLAND (INDONESIA) : A KEY FOR UNDERSTANDING THE GEODYNAMIC OF SUBDUCTION ZONE  <i>Lucas Donny SETIJADJI, Shigeo KAJINO, Yasuaki KOHNO, Didit Hadi BARIANTO, Akmalludin, Akira IMAI, Tetsuya ITAYA and Koichiro WATANABE</i> </p>	433
<p>           USING OF THE ACOUSTIC SIGNALS FOR CONTROL PROCESS  <i>Zdeněk NEUSTUPA and Dagmar LÉTAVKOVÁ</i> </p>	445
<p>           MODELING AND VISUALIZATION FOR RECLAMATION MANAGEMENT OF LANDSCAPE AFFECTED BY UNDERGROUND MINING  <i>Zdeněk NEUSTUPA</i> </p>	451
<p>           THE PHYSICAL MODEL OF COAL OPEN CAST CONTROL IN VIRTUAL REALITY  <i>Michal MARŠOLEK, Michal ŘEPKA and ZDENĚK Neustupa</i> </p>	461
<p>           CHARACTERIZATION OF JEWELRY SECONDARY SLAG AND PROCESSING FOR RECOVERY OF PRECIOUS METALS  <i>Romchat CHAIRAKSA, Kotaro YONEZU, Takushi YOKOYAMA, Akira IMAI, Quanchai LEEPOWPANTH, Pinyo MEECHUMNA and Koichiro WATANABE</i> </p>	467
<p>           SELECTIVE REMOVAL OF CU FROM ACID MINE WATERS BY THE COMBINATION OF ION EXCHANGE AND ELECTRO-WINNING  <i>Luděk JELÍNEK, Richard BURDA, Zdeněk MATĚJKA, Martin PAIDAR and Karel BOUZEK</i> </p>	475
<p>           AUTOMATED CONTROL SYSTEM FOR MICROTUNNELING MACHINE  <i>Teruhisa AWATA, Hideki SHIMADA and Kikuo MATSUI</i> </p>	487

A NEW LINEAMENT EXTRACTION METHOD BY CONSIDERING TOPOGRAPHIC FEATURES AND SPATIAL CORRELATIONS	495
<i>Tomoji SANGA and Katsuaki KOIKE</i>	
SAFETY MANAGEMENT METHANE ON GASSY MINES	503
<i>Vladislav VANČURA</i>	
INFORMATION FILE CONCERNING THE NITROGEN UTILIZATION IN UNDERGROUND MINES "WWW.VSB.CZ/NITROGEN"	509
<i>Alois ADAMUS</i>	
RESEARCH OF NATURAL MINERAL PIGMENTS	513
<i>Peter FECKO, Vladimír CABLIK, Radmila KUCEROVA, Barbora LYCKOVA and Horst GONDEK</i>	
BIODEGRADATION OF SELECTED POLLUTANTS IN WASTES	517
<i>Peter FECKO, Radmila KUCEROVA, Barbora LYCKOVA, Marcela SAFAROVA and Michal REHOR</i>	
STRUCTURAL SIGNIFICANCE OF APATITE FISSION TRACK AGE IN MESO-CENOZOIC STRATA OF KUQA RIVER PROFILE, TARIM BASIN, CHINA	525
<i>Jingchang LI, Toshitaka ARAKI, Hiroto OHIRA, Koichiro WATANABE and Liangjie TANG</i>	
A STUDY ON ALKALI-SILICA REACTION (ASR) ON ANDESITE AGGREGATE	535
<i>Toru FUJII, Kazuo YAMADA and Akira IMAI</i>	
THE GPS SYSTEM APPLICATION FOR THE SELECTIVE MINING OF THE GRAVEL SAND FROM THE WATER LEVEL BY THE GRAB EXCAVATOR	543
<i>Kateřina GOTTFRIEDOVÁ</i>	
HARD REAL TIME SYSTEM FOR PRODUCTIVE INDIAN LONGWALL OPERATIONS	549
<i>Srinivasulu TADISETTY, Kikuo MATSUI, Hideki SHIMADA, and R.N.GUPTA</i>	
VERTICAL WEB PORTAL AS A MEDIATOR BETWEEN USERS AND THEMATIC WEB PAGES	559
<i>Pavel SMUTNÝ</i>	
THE UTILIZATION OF DATA MINING TOOLS FOR PROCESS MONITORING AND CONTROL	565
<i>Milena MACHÁČOVÁ</i>	
HYDROTHERMAL ALTERATION OF CIKORET AND CIURUG UTARA PROSPECT: A CLUE TO THE POSSIBLE EXTENSION OF THE CIURUG VEIN, PONGKOR GOLD MINE, INDONESIA	573
<i>SYAFRIZAL, Koichiro WATANABE and Akira IMAI</i>	
FUNDAMENTAL PROPERTIES OF LUBRICANT IN USING PIPE JACKING	583
<i>Takashi KAWAI, Hideki SHIMADA, Kikuo MATSUI, Jan GOTTFRIED, Suichi FUJITA, Daisuke SATO and Yasuhiro YOSHIDA</i>	

DISTRIBUTION OF INORGANIC CONSTITUENTS IN LOW RANK COALS: AN EXAMPLE FROM PANIAN COALFIELD, SEMIRARA ISLAND, PHILIPPINES	593
<i>Stella Marris LIMOS-MARTINEZ and Koichiro WATANABE</i>	
THE LITHIUM RECOVERY TECHNOLOGIES	603
<i>Marek HOLBÁ, Ayuko KITAJOU, Yasuyuki IKEGAMI, Masanoru MONDE and Kazuharu YOSHIZUKA</i>	
ECONOMIC MODEL OF THE CONURBATION DEVELOPMENT	611
<i>Vladimír KEBO and Vladimír STRAKOŠ</i>	
THE CENTRE OF ADVANCED INNOVATION TECHNOLOGIES AT VŠB - TU OF OSTRAVA	617
<i>Vladimír KEBO and Václav LUKEŠ</i>	
INTELLIGENT MINE AND INNOVATION	623
<i>Vladimír KEBO and Vladimír STRAKOŠ</i>	



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

Barlian DWINAGARA, Budi SULISTIANTO, Ridho. K. WATTIMENA<sup>1</sup>

Suseno KRAMADIBRATA, M. Safrudin SULAIMAN<sup>1</sup>

Kikuo MATSUI<sup>2</sup>

Iwan Dharma SETIAWAN<sup>3</sup>

<sup>1</sup>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*

<sup>2</sup>Kyushu University Fukuoka 812-8581, Japan

<sup>3</sup>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 stopping-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.

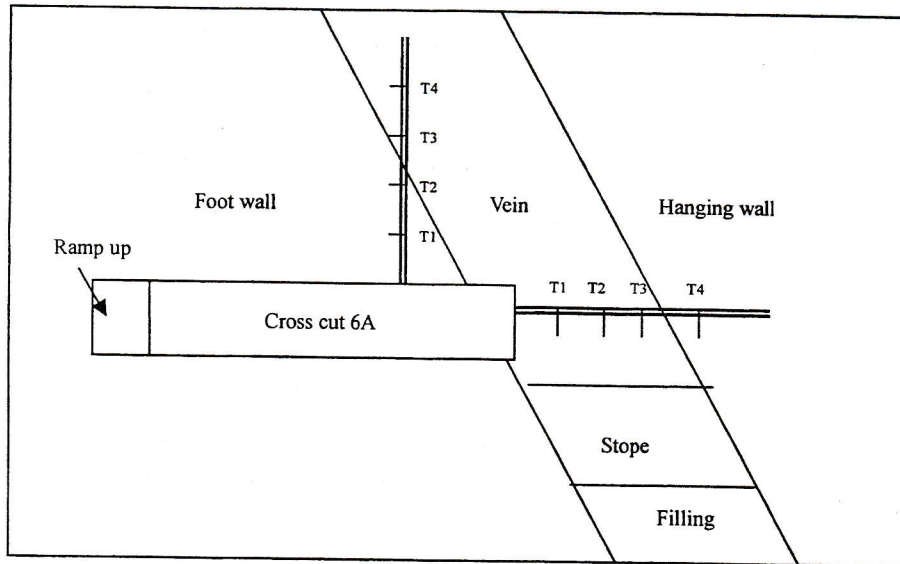


Figure 1. Magnetic anchors in borehole

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,  $T_{4,3}$  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:

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

Where:

- $\Delta L$  = 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 <sub>1</sub>	1123 mm	Foot wall	1146 mm	Vein
T <sub>2</sub>	2411 mm	Foot wall	2365 mm	Vein
T <sub>3</sub>	3892 mm	Vein	3867 mm	Vein
T <sub>4</sub>	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,

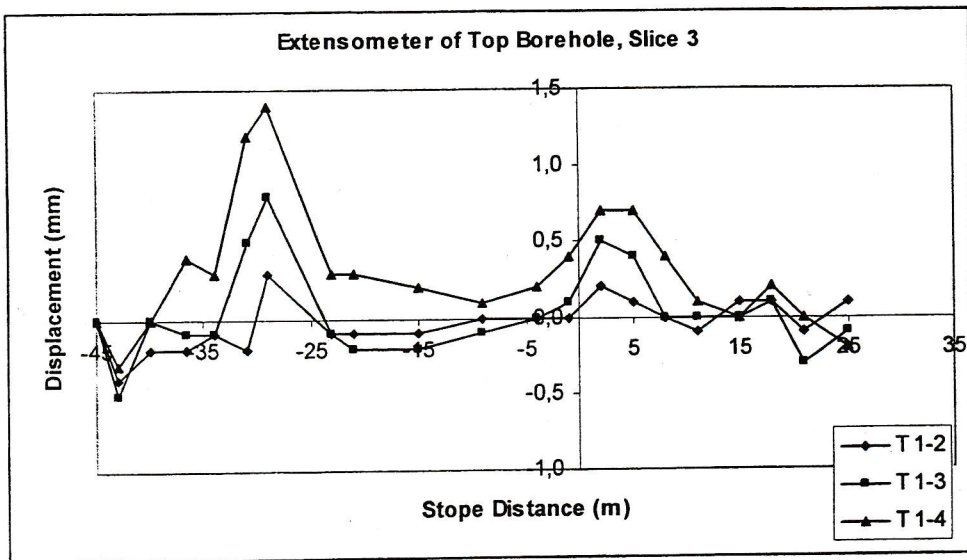


Figure 2. Accumulative displacement along top borehole

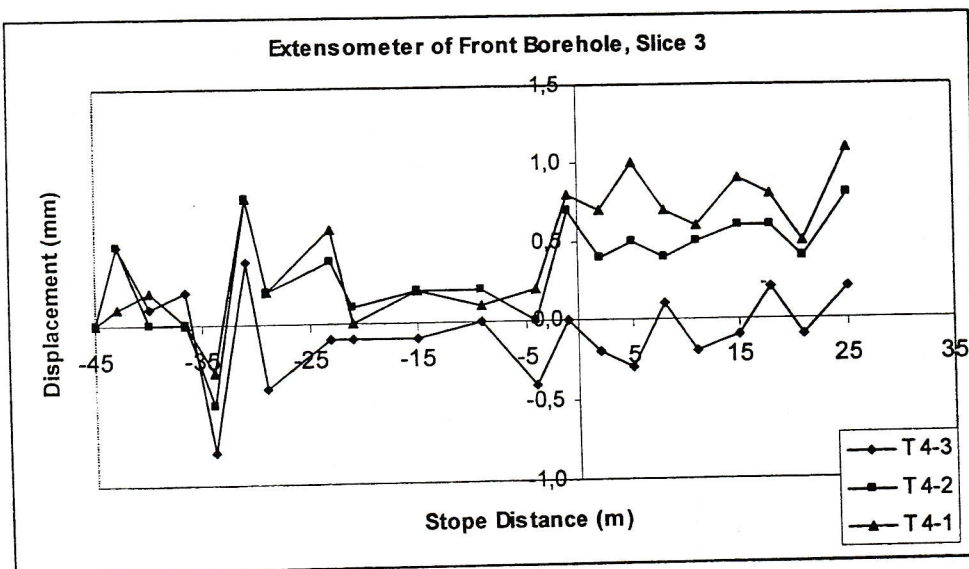


Figure 3. Accumulative displacement along front borehole

## 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  $\sigma_1$  and 0.385 MPa for  $\sigma_3$  (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.

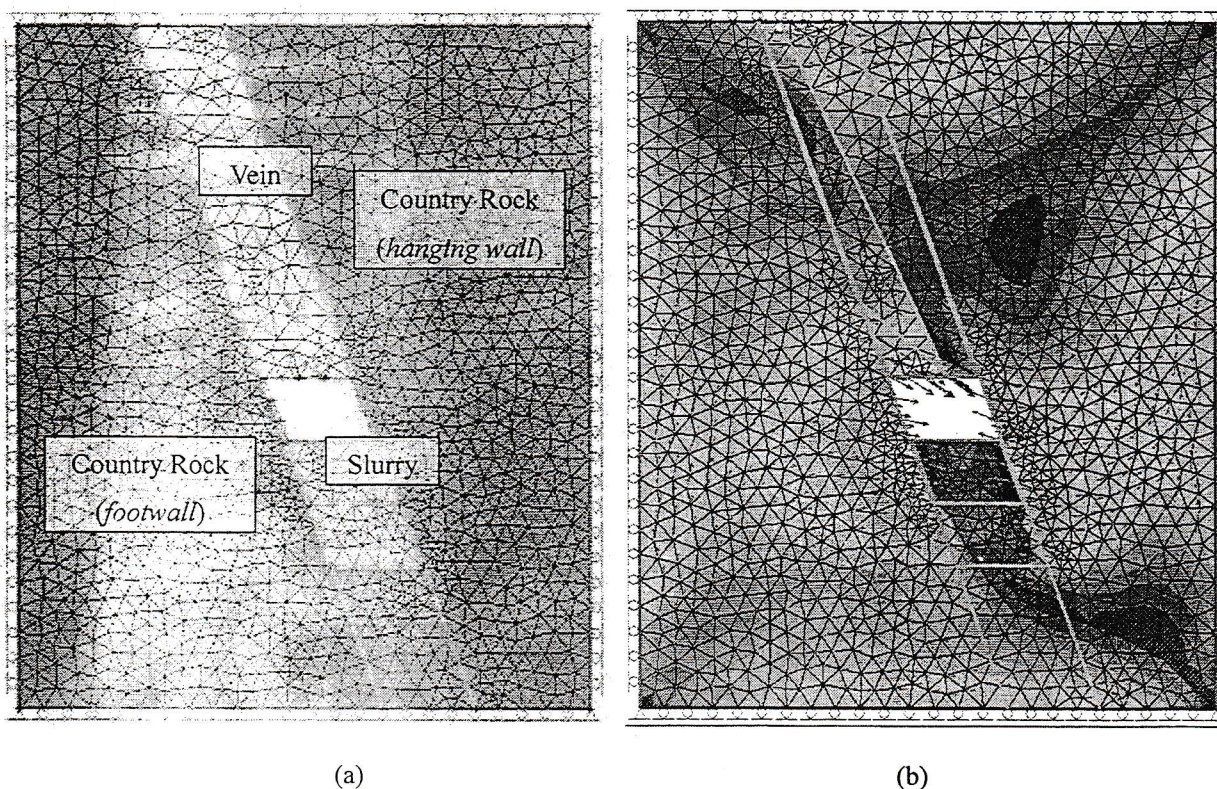


Figure 4. FEM Modelling: (a) Model, (b) Result

## 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 <sub>1-2</sub>	T <sub>1-3</sub>	T <sub>1-4</sub>	T <sub>4-3</sub>	T <sub>4-2</sub>	T <sub>4-1</sub>
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 from the stope. This condition might cause downward movement of the vein. The fractures have also been observed by a borehole camera inserted in the front borehole.

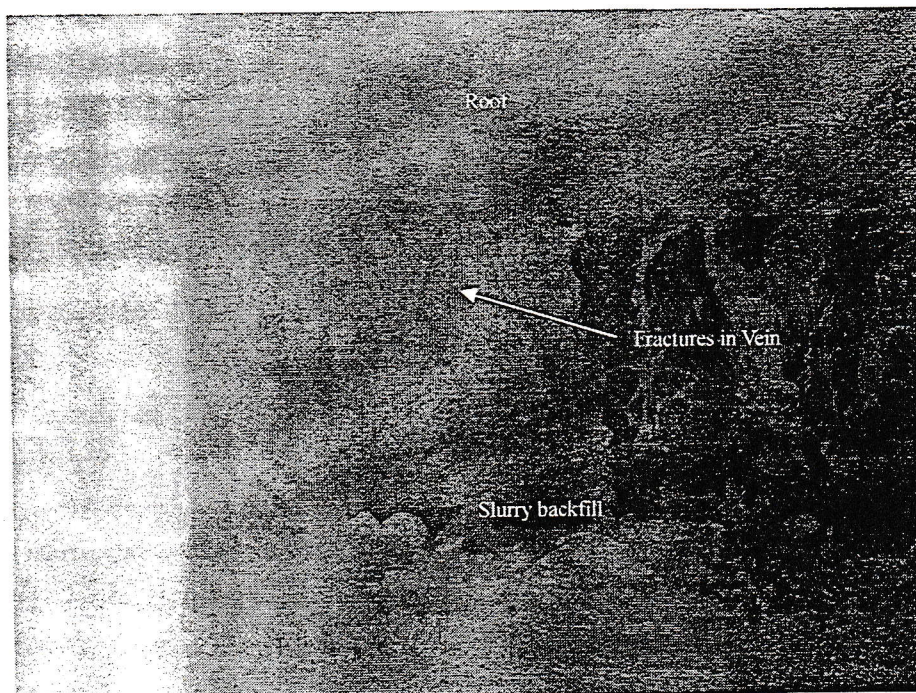


Figure 5. Fractures in vein

Based 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 discontinuities which directions (strike/dip) were N338°E/40° at the depth of 140 cm and N356°E/65° 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°E/84°.

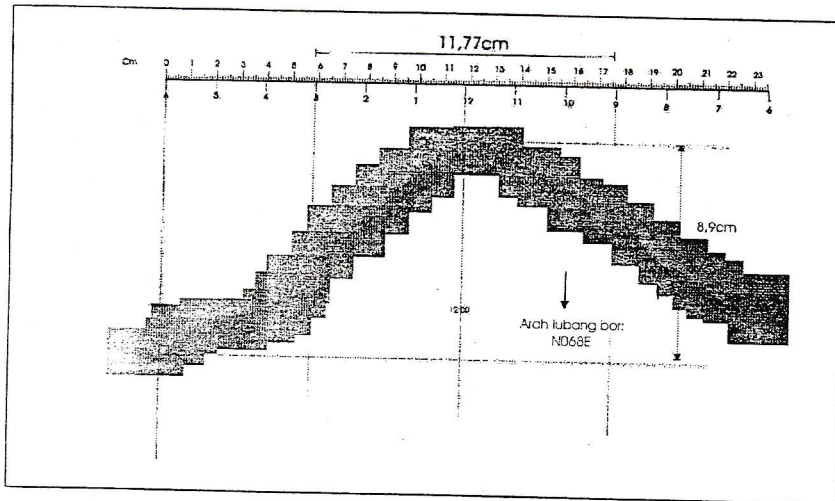


Figure 6. Crack at the depth of 140 cm

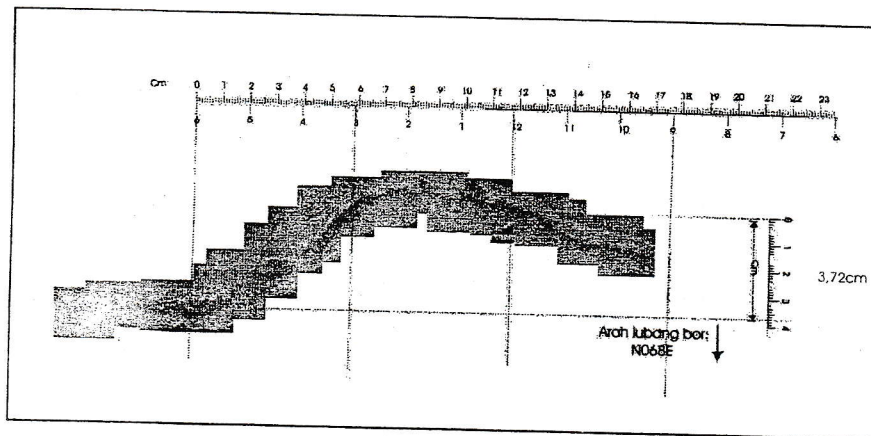


Figure 7. Crack at the depth of 265 cm

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.

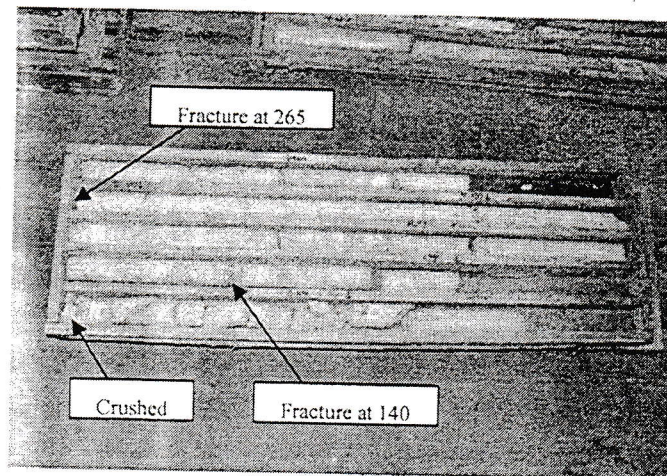


Figure 8. Core box of front borehole

## 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<sub>1-2</sub> 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.

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