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FIELD STRESSES AT THE KIDD CREEK MINE, TIMMINS

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by

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ABSTRACT

In the context of extensive geotechnical and rock mechanics investigations to obtain background data for stability analysis, field stress determinations were conducted at the Kidd Creek Mine, Timmins.

An evaluation of present and previous stress determination data, obtained at various depths of the mine, indicate that the stress regime is similar to those observed in deep hard rock mines in Northern Ontario. The maximum pre-mining stress is EW/horizontal and intermediate pre-mining stress is NS/sub-horizontal in relation to the geographic north. The vertical stresses are in close agreement with the overburden pressure and an average horizontal stress/vertical stress ratio of 1.2 to 2.2 exists.

From the stress gradients obtained at depths between 488 to 1382 m, the input stresses for computer modelling can be approximated as:

Vertical stress: 0.027 MN/m^3 x Depth (m) in MPa

Pre-mining stress perpendicular to orebody: 2.2 x Vertical stress

Pre-mining stress parallel to orebody: 1.5 x Vertical stress.

- pre-mining stress
- rock mechanics
- underground mining
- Kidd Creek mine

Key words: Pre-mining stress; Stress gradients; Triaxial and biaxial overcoring measurements.

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CONTRAINTES EXERCÉES DANS LE TERRAIN À LA MINE DE KIDD CREEK, TIMMINS

par

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RÉSUMÉ

Des études géotechniques exhaustives ainsi que des études de la mécanique des roches ont été effectuées en vue d'obtenir des données de base pour des analyses de stabilité. Dans le cadre de ces études, on a procédé à la détermination des contraintes exercées dans le terrain à la mine Kidd Creek, à Timmins.

Une évaluation des données existantes et des données antérieures relatives à la détermination des contraintes, obtenues à diverses profondeur de la mine, indiquent que le régime de contraintes est semblable à celui qui peut être observé dans les mines profondes de roches dures dans le nord de l'Ontario. La contrainte maximale exercée dans le terrain avant l'exploitation est horizontale, en direction E-O, tandis que la contrainte intermédiaire N-S, est sous-horizontale, en direction du Nord géographique. Les contraintes verticales correspondent étroitement à la pression géostatique et le rapport moyen de la contrainte horizontale et de la contrainte verticale est de 1,2 à 2,2.

À partir des gradients de contraintes obtenus à des profondeurs variant de 488 à 1 382 m, les données sur les contraintes qu'il est possible d'utiliser à des fins de modelage assisté par ordinateur sont approximativement de :

Contrainte verticale : 0,027 MN/m^3 X Profondeur (m) en MPa
Contrainte avant l'exploitation, perpendiculaire au corps de minerai : 2,2 X Contrainte verticale
Contrainte avant l'exploitation, parallèle au corps de minerai : 1,5 X Contrainte verticale.

Mots-clé : Contrainte avant l'exploitation; gradients de contraintes; Mesures triaxiale et bisaxiale du surcarottage.

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INTRODUCTION

The Kidd Creek Mine is situated 27 km north of Timmins within the Abitibi Greenstone Belt, as shown in Figure 1. A detailed study of the mine area reveals a complex geological structural setting (1). The massive base metal orebodies are steeply-dipping structures with a northerly trend. The deposit has a maximum dimension of 670 x 170 m, extending some 1500 m below surface.

In 1972, a cooperative rock mechanics research project was initiated between Kidd Creek Mines (Texasgulf Canada Ltd.) and the Mining Research Laboratories of CANMET. To evaluate the ground stability and to contribute to the mining design, extensive geotechnical and analytical studies on the open pit and around the underground stopes were carried out (2-4). As the mining progressed in depth, pre-mining field stresses were measured to obtain background data for stability analysis and the determination of optimum mining methods (5-7).

To improve stability and productivity, different aspects of rock mechanics on ground control, the blasthole stoping method, and backfill were investigated (8-10).

As a continuation of the stress determination program, stress measurements were recently carried out on the 2400 (732 m) and 4600 (1382 m) levels. The present report provides the results and incorporates the previous stress data obtained at the mine.

Including the present measurements, a total of forty-nine overcoring tests, using CSIR biaxial and triaxial strain cells, were taken on the 1600(488 m), 2400 (732 m), 2800 (853 m), 3600 (1041 m), and 4600 (1382 m) levels.

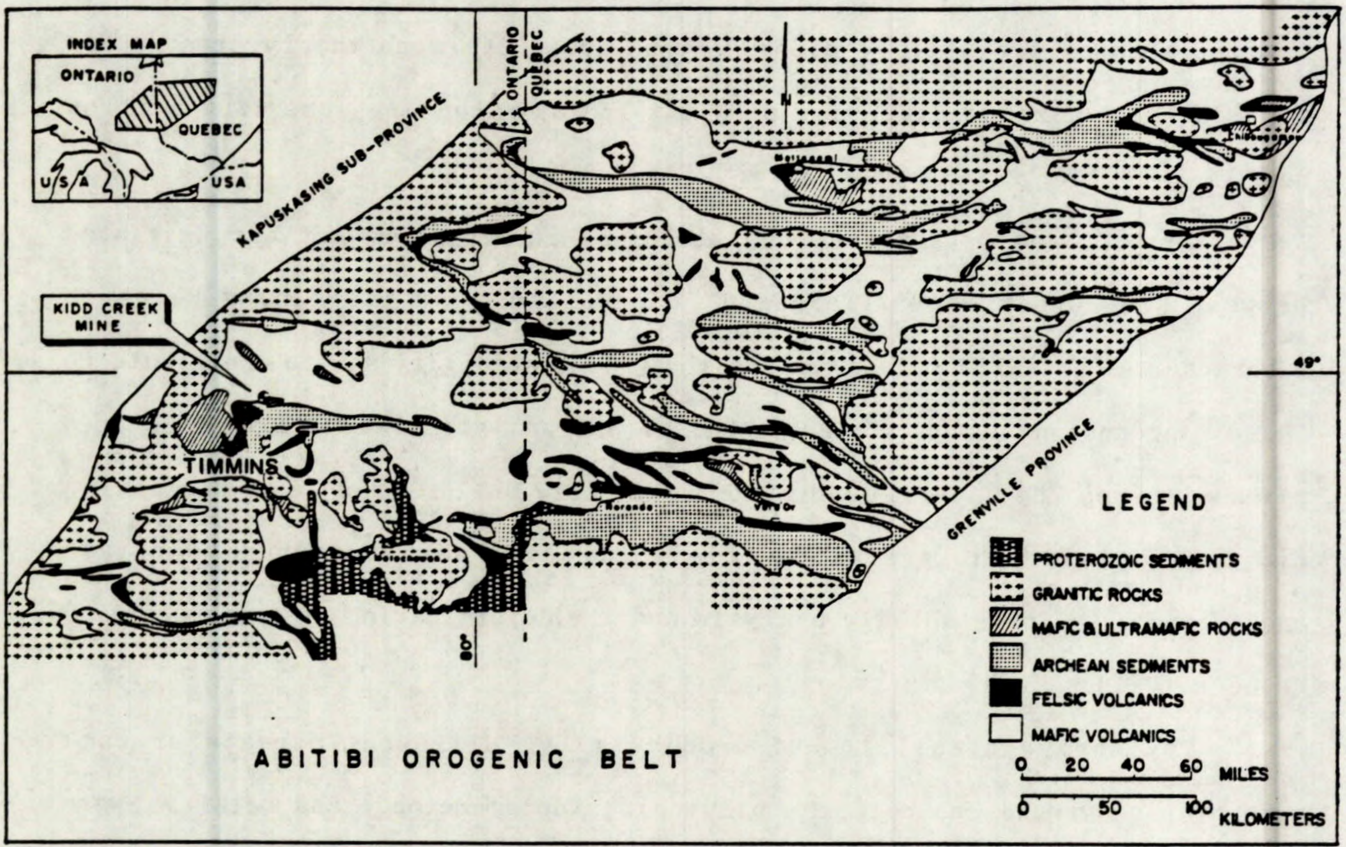

Fig. 1 - Regional geology (1), and the location of Kidd Creek Mine.

FIELD STRESS MEASUREMENTS

Strain recovery measurements were carried out on the 2400 and 4600 levels. Test sites were selected in the development drifts away from the influence of mining. Test holes were drilled perpendicular to the main structural trend and two successful overcoring measurements were performed at each stress determination site. Table 1 provides the elastic strain recoveries from triaxial strain cell measurements.

The results of stress tensor calculations and the principal compressive stress magnitudes and orientations in relation to the mine coordinate system are given in Table 2. The elastic constants for the rocks intersected in the test holes were determined from available core specimens, as given in Table 3. The mean values of the elastic moduli and Poisson's ratios obtained from the individual test sites were used for the stress calculations.

Laboratory testing indicated poor bonding quality in the KC 24-1 test, which confirmed some erratic strain readings observed during the overcoring measurement. Therefore, the test results were excluded from the final evaluations. The remaining overcored test specimens showed a linear gauge response in the compression testing, indicating good bonding.

EVALUATION OF FIELD STRESSES

The results from recent and previous field stress determinations carried out at the Kidd Creek Mine are summarized in Table 4. The stress components in E-W, N-S, and vertical directions are calculated on the basis of a least squares analysis. Shear stresses of low magnitudes, or tensional, were determined from stress analysis. The orientation of the principal compressive stresses are given in relation to the geographic north. Table 4 also provides the pre-mining horizontal stresses perpendicular and parallel to

Table 1 - Strain recovery from triaxial strain cell measurements.

Location	Test No.	Test Depth (m)	Elastic Strain Recovery ($x10^{-6}$) Gauge No: 1	2	3	4	5	6	7	8	9	10	11	12	SI* Rosette # 1	2	3
2400 Level	KC 24-1	4.15	250	495	550	290	40	115	130	60	1160	1015	390	560	15	5	25
	KC 24-2	4.80	320	810	310	-150	1635	310	165	1545	720	615	310	435	30	55	20
4600 Level	KC 46-1	5.85	510	130	165	545	1470	1400	240	290	805	220	195	765	0	20	15
	KC 46-2	7.40	340	520	150	-40	1900	1050	240	1050	1115	575	95	620	10	40	15

*Strain Invariance: sum of orthogonal strains ($\varepsilon_1 + \varepsilon_3 = \varepsilon_2 + \varepsilon_4$).

Test hole data: 2400 Level: Coordinates 65750 E, 65583 N, Azimuth/dip 028°/+8°.
4600 Level: Coordinates 65527 E, 65665 N, Azimuth/dip 346°/+9°.

Table 2 - Stress components and principal stresses from field stress determinations at 2400 and 4600 levels (stress in MPa).

Location	Test No.	Stress Components (Standard errors in brackets) σ_{EW}	σ_{NS}	σ_{V}	τ_{EN}	τ_{NV}	τ_{VE}	STDV Error*	Principal Stresses Magnitude/Orientation σ_1	σ_2	σ_3
2400 Level	KC 24-1	28.00 (3.80)	32.65 (6.24)	18.75 (3.80)	5.40 (2.60)	-3.50 (2.60)	12.75 (2.20)	1.27 20%	40.90 195/27	29.10 093/22	9.40 330/54
	KC 24-2	54.2 (1.18)	33.9 (1.90)	22.2 (1.18)	5.20 (0.80)	-5.15 (0.80)	-11.35 (0.70	0.40 6%	57.3 071/14	37.8 334/27	15.2 185/60
4600 Level	KC 46-1	60.75 (1.50)	28.25 (0.90)	37.55 (0.90)	-9.00 (0.70)	5.20 (0.70)	-13.30 (0.50)	0.25 5%	65.90 290/18	42.30 044/51	18.35 118/33
	KC 46-2	68.55 (4.30)	41.65 (2.60)	33.00 (2.60)	8.80 (2.00)	-8.80 (2.00)	-9.05 (1.50)	0.67 10%	75.05 071/15	42.05 334/25	26.95 190/60

Note: Stress components and the principal stresses orientation (Azimuth/dip in degrees) related to the Mine coordinate system (Mine Grid North 20° clockwise from True North).

* Average standard errors for stress components (in percent).

Table 3 - Determination of elastic modulus and Poisson's ratio from compression testing.

Location	Sample No.	Elastic Modulus (GPa)	Poisson's Ratio ν	Rock Type
2400 Level	KC 24-2*	65.90	0.32	Rhyolite (Chloritic)
	KC-1**	64.15	0.30	
	Mean:	65.02 ± 1.24	0.31 ± 0.01	
4600 Level	KC 46-1*	94.35	0.32	Andesite/Diorite
	KC 46-2*	83.10	0.27	
	KC-1**	80.90	0.15	
	KC-2**	78.27	0.14	
	KC-3**	92.07	0.22	
	KC-4**	99.03	0.23	
	Mean:	87.95 ± 8.34	0.22 ± 0.07	

*Radial compression test of the overcored hollow core cylinder; values obtained from strain readings of the axial and circumferencial gauges of the strain cell, maximum load 20.0 MPa.

**Uniaxial compression test on solid core cylinder; values obtained from strain gauge readings during unloading cycle; maximum load 31.0 MPa.

Note: Core diameter 142 mm; ratio height/diameter: 2.5.

Table 4 - Field stresses at the Kidd Creek Mine (stress in MPa).

Location	Depth (m)	Horizontal Stress		Vertical Stress	Principal Stresses (x) Magnitude/Orientation			Horizontal Stress *		Method	Ref.
		σ_{EW}	σ_{NS}	σ_V	σ_1	σ_2	σ_3	⊥ O/B	‖ O/B		
1600 Level	488	31.9	25.4	13.4	33.2	26.8	10.7	29.0	20.0	B	(5)
				(13.2)*	094/06	186/23	350/66				
2400 Level	732	62.7	65.1	43.9	72.6	64.7	34.4	43.0	30.0	B	(5)
				(19.7)	258/19	358/25	135/58				
		54.2	33.9	22.2	57.3	37.8	15.2			T	(**)
					091/14	354/37	205/60				
2800 Level	853	51.0	52.5	20.9	53.3	51.9	19.1	50.0	34.0	B	(5)
				(23.0)	250/10	342/09	112/77				
	Ave.	54.0	41.4	36.5	61.5	44.6	26.0			T	(6)
	3 tests				078/13	170/15	287/72				
3600 Level	1041	39.7	50.1	34.4	54.8	36.2	33.2	61.0	42.0	B	(7)
				(28.1)	353/13	263/01	170/77				
4600 Level	1382	60.8	28.2	37.5	65.9	42.3	18.3	80.0	55.0	T	(**)
				(37.3)	310/18	064/51	208/33				
		68.5	41.6	33.0	74.0	42.0	27.0			T	(**)
					091/15	354/23	210/60				

(x) Principal stresses orientation (Azimuth/dip in degrees) related to the Geographic North.

(*) Vertical stress and horizontal stresses perpendicular (⊥O/B) and parallel (‖O/B) to the orebody obtained from pre-mining stress gradients:

Vertical stress = 0.027 MPa/m
Pre-mining stress perpendicular to O/B = 0.058 MPa/m
Pre-mining stress parallel to O/B = 0.040 MPa/m.

Methods of the overcoring measurements: CSIR Triaxial strain cell (T); CSIR Biaxial strain cell (B) with standard three drill hole set-up.

(**) Results from the present stress measurements.

the orebody as well as the vertical stresses determined from the stress gradients. The average stress gradients from measurements at depths between 488 to 1382 m were obtained from the pre-mining stress components, as shown by the data plotted in Figure 2.

A close agreement exists between the stress data using different methods for the overcoring measurement. However, the biaxial method resulted in higher standard errors for the stress tensor components. The stress values from triaxial measurements on the 2800 test site were combined. The averaged values were comparable with the biaxial measurements obtained at the same test site. The measured vertical stress, however, was about 30% higher than the calculated overburden stress.

On the 2400 level, anomalously high stresses were determined from the previous measurements, with the magnitude of the measured vertical stress being two times higher than the calculated overburden pressure. Current stress determinations, with the test site located about 300 m away at the same mine level, did not indicate any extreme stress values. This confirmed that the previously measured high vertical and horizontal stresses were indicative of a local stress concentration. The extreme stress values were not used for the evaluation of pre-mining stress gradients.

The orientation of the principal stresses for the individual stress determination sites and the major principal stress directions are illustrated in Figure 3. There is a close agreement between the principal stress orientations on the 1600, 2400, 2800 and 4600 levels. The mean orientation of the principal stresses with respect to the geographic north are as follows:

Principal Stress		Azimuth/Dip
Major, σ_1	:	$090^{o}/13^{o}$
Intermediate, σ_2	:	$160^{o}/23^{o}$
Minor, σ_3	:	$270^{o}/63^{o}$

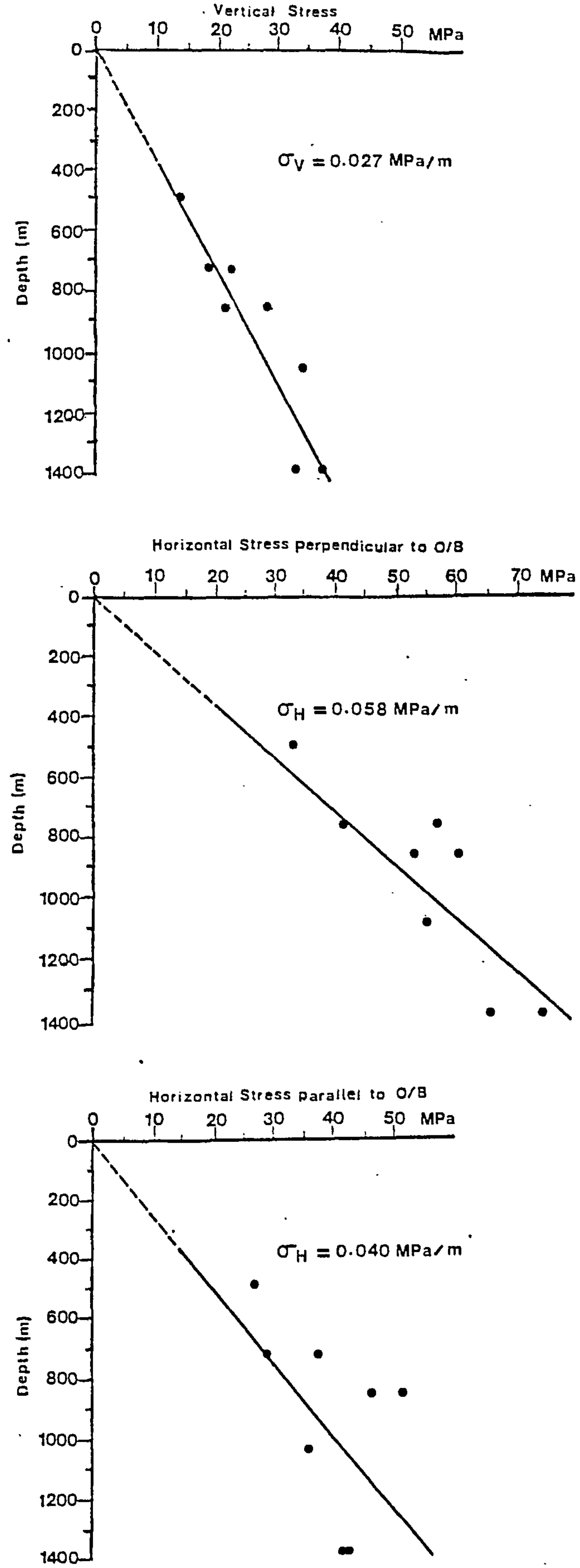

Fig. 2 - Pre-mining stress components at depth between 488 and 1382 m.

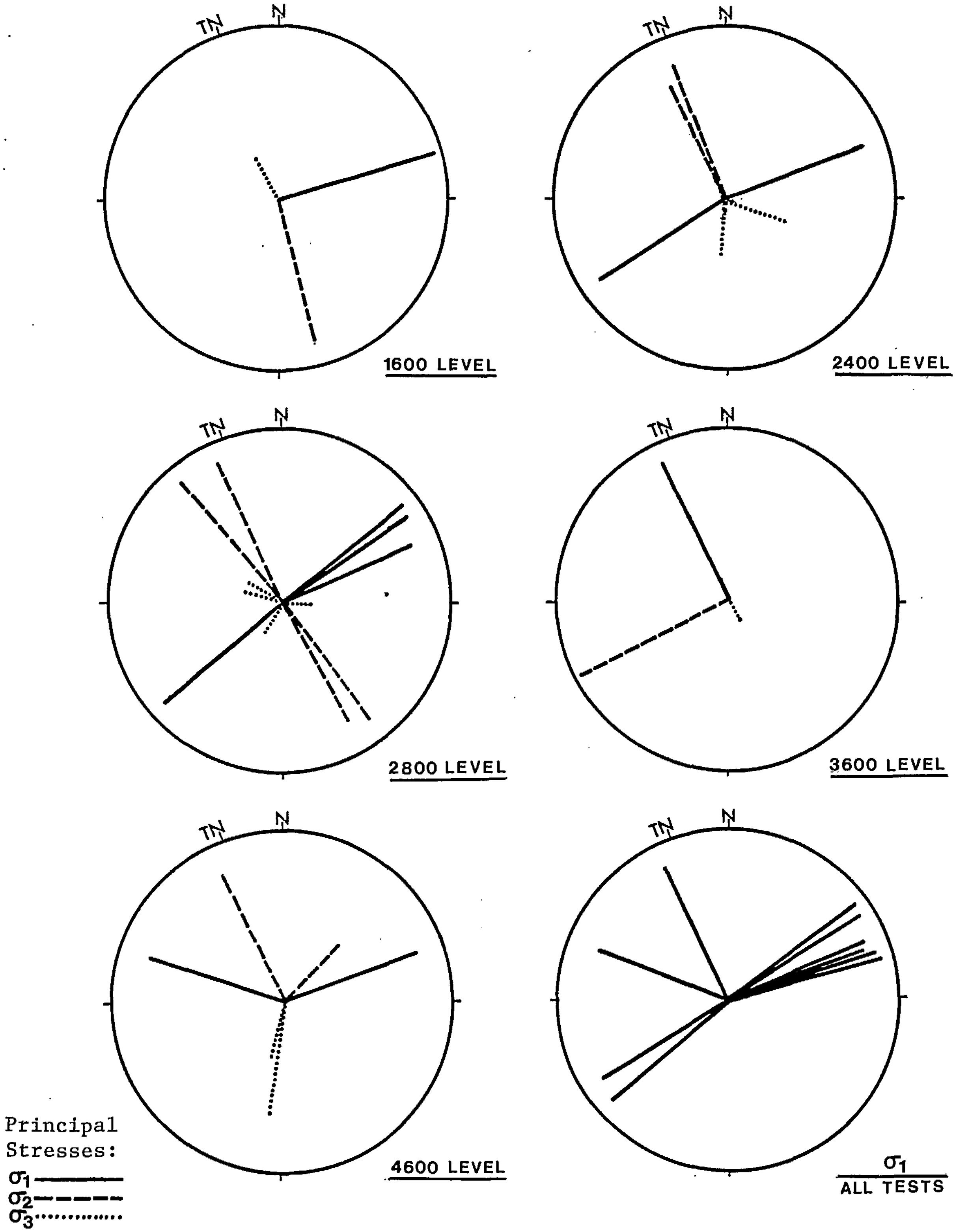

Fig. 3 - Orientation of the principal compressive stresses in relation to the mine coordinate system in an equal area net, lower hemisphere projection; (Mine Grid North 20° clockwise from True North).

On the 3600 level the stress magnitudes were within the range of data obtained at the mine, but the major principal stress direction shows rotation to a north-south direction compared with the main east-west trend. This deviation can be explained by a possible interference of mining openings on the stress measurement site, and to some extent, inaccuracy in orientation of the strain cells. Therefore, on the 3600 level, further measurements away from the mining influence are required to determine whether the stress data were indicative of a local or regional stress regime at this section of the mine.

With regard to the main trend of steeply-dipping orebodies, generally the maximum horizontal stress is perpendicular while the intermediate horizontal stress parallels the orebodies. It is recommended that this relationship should also be applied on the 3600 level until further information is available.

CONCLUSIONS

From the ground stress determinations the following major points can be established:

1. The stress regime is similar to those observed in deep hard rock mines in Northern Ontario.
2. The maximum pre-mining stress is east-west/horizontal, intermediate pre-mining stress is sub-horizontal in a northerly direction,and the measured vertical stresses approach the overburden load.
3. The Horizontal stressis greater thanverticalstress with theaverage horizontal stress/vertical stress ratio ranging from 1.2 to 2.2. A maximum to intermediate horizontal stress ratio of 1.4 exists.
4. Based on stress gradients obtained from the pre-mining stress components at depths between 488 to 1382 m, the most suitable input stresses for computer modelling can best be approximated as follows:

Vertical stress : 0.027 MN/m^3 x Depth (m) in MPa

Pre-mining stress perpendicular to orebody : 2.2 x Vertical stress

Pre-mining stress parallel to orebody : 1.5 x Vertical stress.

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REFERENCES

1. Walker, R.R. and Mannard, G.W., "Geology of the Kidd Creek Mine - a progress report"; CIM Bull, vol 67, No. 752, pp 41-57; December 1974.

2. Herget, G. and Miles, P., "Mining research at the Kidd Creek Mine, Timmins - Part I, geotechnical investigations"; Division Report MRP/MRL 74/33(IR), CANMET, Energy, Mines and Resources Canada; February 1974.

3. Yu, Y.S., "Mining research at the Kidd Creek Mine, Timmins - Part 4: the effect of residual tectonic stresses on stability of the excavations"; Division Report MRP/MRL 75-99(IR), CANMET, Energy, Mines and Resources Canada, February 1975.

4. Hedley, D.G.F., Herget, G., Miles, P. and Yu, Y.S., "CANMET's rock mechanics research at the Kidd Creek Mine"; Division Report MRP/MRL 79-11(TR), CANMET, Energy, Mines and Resources Canada; May 1979.

5. Herget, G. and Miles, P., "Underground stress determinations using the doorstopper method at Timmins, Ontario"; Division Report MRP/MRL 76-148(TR), CANMET, Energy, Mines and Resources Canada; October 1976.

6. Herget, G., "Field testing of modified triaxial strain cell equipment at Timmins, Ontario"; Division Report MRP/MRL 77-2(IR), CANMET, Energy,

Mines and Resources Canada; September 1976.

7. Quesnel, W.J., "In situ stress measurements, No. 2 mine, 36-3 sub-level"; Ground Control Section, Kidd Creek Mine; (Stress analysis by B. Arjang, CANMET, Energy, Mines and Resources Canada); May 1985.

8. Yu, T.R., "Ground control at Kidd Creek Mine"; Underground Rock Engineering, CIM Special Vol. 22; 1980.

9. Yu, T.R. and Counter, D.B., "Backfill practice and technology at Kidd Creek Mines"; CIM Bull, 71(856), 1983.

10. Yu, T.R. and Quesnel, W.J., "Applied rock mechanics for blasthole stoping" in Geomechanics Applications in Underground Hardrock Mining; SME-AIME, 93-107; 1984.