

RAPPORT FRÅN RESA I USA 1-20.9.1974

Finn Ouchterlony

DS 1974:14

10.12.1974

STIFTELSEN
SVENSK DETONIKFORSKNING
SWEDISH DETONIC RESEARCH FOUNDATION

VINTERVIKEN - 117 48 STOCKHOLM
SWEDEN

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Sammanfattning

Rapporten innehåller korta sammanställningar av mina intryck från en studieresa i USA. Den omfattar dels en bergmekanik-kongress dels besök i gruvor och på forskningsinstitutioner. Kongressen gav tillfälle till att knyta intressanta kontakter av vilka en följdes upp med ett institutionsbesök. Gruvbesöken gav en bra översikt över olika gruvtyper i det aktuella området och deras bergmekaniska problem.

1. Inledning

Undertecknad gjorde en studieresa i USA under tiden 1-20 september 1974 och besökte därvid en kongress, ett flertal gruvor och några forskningsinstitutioner. Ämnesområdena var bergmekanik, brottmekanik, bergsprängning och bergbrytning.

Rapporten innehåller korta sammanställningar. Mer detaljerade beskrivningar av besöken och kommentarer till dessa har lagts i appendix. Där finns också listor över personliga kontakter, tekniska informationsblad och listor på referenser som arkiverats på Stiftelsen.

2. ISRM:s tredje kongress i bergmekanik

Denna kongress ägde rum i Denver, Colorado veckan 1-7 sept. och var uppdelad på fem teman med delvis parallella sessioner. Dessa tema var:

1. Bergarters och bergmassors fysikaliska egenskaper
2. Tektonofysik
3. Ovanjordsarbeten
4. Underjordsarbeten
5. Sönderbrytningsmetoder

P.A. Persson vid Stiftelsen hade gjort en översikt över tema 5 /1/ och höll också en muntlig inledning till den sessionen som kommer att presenteras på BeFo:s bergmekanikdag 1975 /2/. Han gjorde sedan en sammanfattning av inlämnade bidrag. Nils Lundborg vid Stiftelsen presenterade sin statistiska brotteori under tema 1 /3/ och jag redogjorde för brottmekanikens användning vid sprängning under tema 5 /4/. Ytterligare ett svenskt bidrag presenterades muntligen, av Sten Bjurström /5/. En lista på de föredrag som presenterades vid kongressen finns i appendix A.

Kongressen var ambitiöst upplagd med simultantolkning till tyska och franska. Antalet deltagare var c:a 1000 st. Bredden medförde att man, förutom diskussioner inom sitt eget fackområde, kunde följa allmänbildande föredrag inom närliggande områden. Kongressens omfattning var nog så stor och stel att det mesta som presenterades rimligen redan publicerats på annat håll. De diskussionskontakter jag fick genom mitt föredrag bör emellertid vara av intresse för framtiden. I appendix B följer några diskussionsanteckningar från tema 5 - sönderbrytningsmetoder och ett erratum.

Kongressen omfattade också ett flertal utflykter av turistkaraktär i

vilka jag deltog. I kongresshotellet hade flera olika instrumenttillverkare och konsultföretag ordnat en utställning. Några prospekt därifrån finns i appendix C. Kongressen avslutades för min del med ett gruppbesök på laboratorierna vid US Bu Reclamation (motsvarar ungefär Vattenfall), US Geol. Survey (motsvarar SGU) och US Bu Mines. En del material från US Bu Mines finns i appendix D. Detta omfattar IR-detektering av löst berg i gruvor mm., pulsreflektionsmätningar av mark-sättningar samt automatisk detektering och lokalisering av seismisk aktivitet i gruvor.

3. Gruvor i västra Kanada och nordvästra USA

Efter kongressen deltog jag 8-15 sept. i en rundresa som kongressarrangörerna ordnat. Atlas Copco betalade min resa. Efter rundresan besökte jag dessutom två gruvor utanför Denver den 16-17 sept.

Avsikten med resan var att ge en överblick av hur gruvorna använder bergmekaniken i praktiken. Då det pågick en gruvstrejk i området som vi passerade kom rutton att ändras något. Dessutom inställdes ett besök på Robbins fabrik i Seattle. Resan blev något oorganiserad då den man som planerat den lastat över ansvaret på andra strax innan resan började. Våra ledare kom att bli Karl Niermeyer från Laurich Kennedy Associates i Seattle och Robert E. Simpson från US Bu Mines i Spokane. De ordnade så att det mesta fungerade bra. En deltagarlista finns i appendix E.

Resan sträckte sig från Klippiga bergen i öster till Stilla havet i väster och området var ofta mycket vackert.

Här följer en sammanställning av resan:

8.9. Flygresan från Denver, Colorado, till Cranbrook i British Columbia där vi övernattade.

9.9. Bussresa från Cranbrook via Fernie till Elkford och vidare till dagbrottet hos Fording Coal Operation i B.C. Efter gruvbesöket hos Fording, buss tillbaka till Elkford där vi passerade två av Kaisers kolgruvor och vidare till Frank i Alberta där vi såg ett mycket stort rasområde. Sedan återvände vi till Fernie med bussen och där övernattade vi. Närmare information om gruvorna finns i appendix F.

10.9. Bussresa från Fernie B.C. över gränsen till Libby i Montana, där vi besökte den nästan färdiga Koocanusadammen som i färdigt skick kommer att kosta ca 400 miljoner US \$ och då leverera 500 MW. Dammen, som är en gravitationsdamm, var bergmekaniskt intressant av två skäl, dels för kontrollen av porttrycket i gränsytan mellan dammen och underlaget för att förhindra glidning men också för slänt stabiliseringen med bergankare vid ena fästet där en stor bergkil redan glidit ut. Åtterresan med buss via Bonners Ferry i Idaho till Cranbrook, varifrån vi flög till Kelowna B.C. Därifrån buss till Kamloops B.C. där vi övernattade.

11.9 Bussresa till Merrit och besök på Craigmontgruvan. Man bryter kopparmalm med skivrasmetoden, se appendix G. Därifrån vidare med buss till Princeton B.C. och ny övernattnig.

- 12.9. Buss till Similkameengruvan, som är ett dagbrott för kopparmalm. Därifrån genom Manningparken till Hope B.C. där vi passerade ännu ett rasområde och vidare till Vancouver vid Stilla havskusten. Från Vancouver flög vi via Seattle i Washington till Spokane som ligger i samma delstat. Övernattning. Närmare information om gruvbesöket i appendix H.
- 13.9. Bussresa från Spokane till Mullan i Idaho. Där gjorde vi ett besök på Lucky Friday-gruvan som bryter bly-, zink- och silverhaltig malm med igensättningsmetoden. Man hade bl.a. monterat ett elektroniskt system för kontinuerlig detektering och lokalisering av seismisk aktivitet i gruvan, se appendix I. På tillbakaresan till Spokane passerade vi ett monument över de 89 gruvarbetare som dog vid Sunshine-katastrofen för två år sedan.
- 14.9. Besök på US Bu Mines nya forskningscenter i Spokane. Se appendix J.

Efter rundresan stannade jag en dag i Spokane och besökte värdsutställningen "Expo-74". Måndag den 16.9 flög Sten Bjurström och jag tillbaka till Denver där Charles Jude vid American Metals Climax Corp. tog emot oss. Han visade oss på måndagen AMAX datacentral och tisdag 17.9 två av företagets molybdengruvor, dels Hendersongruvan som inte är i drift än samt Climaxgruvan. Närmare uppgifter om dessa finns i appendix K och för fallet Climax också i Nils Lundborgs reserapport /6/. Jag vill säga att chefen för Hendersongruvan, Bob Jones, hade hört talas om Nonel tändsystemet och sade sig vilja använda det i stor skala under tillredningsarbetet.

Avslutningsvis vill jag säga att rundresan gav mig en bra inblick i de förhållanden som råder i gruvorna i området. Besöken omfattade dels dagbrott och underjordsgruvor med olika brytningssystem (skivras-, igensättnings- och blockrasbrytning), dels kol- och metallgruvor (koppar, bly, zink, silver och molybden) samt gruvor med olika bergmekaniska förutsättningar. Kolet och den anrikade malmen från de tre kanadensiska gruvorna såldes till Japan.

4. Besök på universiteten i Minnesota och Maryland

Min resa avslutades med besök på två universitetsinstitutioner. Det första var University of Minnesotas institution för gruv och anläggningsteknik där professor Charles Fairhurst verkar. Jag träffade främst dr Tom Bligh och vi diskuterade frågor av gemensamt intresse, bl.a. hans uppfattning kontrollerad sprängning./7/. Övriga personer jag träffade var prof. Charles Nelson, dr Francois Cornet samt Michael Vogeles och Krishna Sinha. Nils Lundborg har informerat om deras verksamhet i /6/. I appendix L finns en värdefull lista över personer, som någon gång arbetat för prof. Fairhurst, och deras adresser.

Den 19-20.9 besökte Nils Lundborg och jag University of Marylands mekanikinstitution där Anders Ladegaard-Pedersen från Stiftelsen arbetat sedan årsskiftet 1973-74. Institutionsföreståndare är prof. James Dally, där finns sammanlagt 30 professorer och ca 15 andra medarbetare. De viktigaste arbetsområdena är:

1. Solenergi, kylning och luftkonditionering ~ 150.000\$/år i 3 år
2. Sprickbildning och bergbrytning ~ 200.000\$/år
3. Luftmotståndet hos truckar ~ 120.000\$/år
4. Samt ett tiotal mindre enmansprojekt á 20-30.000\$/år.

William Fourny och David Holloway arbetar tillsammans med Anders L-P. på sprickbildning och bergbrytningsprojektet. Deras apparatresurser är också goda, de har bl.a.:

1. En Cranz-Schardin kamera med 16 bilder med minst 1 μ s mellan varje. Blixtbatteriets kapacitet är 0.5 μ F vid ± 15 kV. Som modellmaterial används Homalite 911 (CR-39) och Homalite 100. James Dally säljer liknande kameror för ca 12.000 \$.
2. En Beckman Whitley 330, "streak" och "framing" kamera med roterande spegel. Upp till 900.000 bilder/s används kväve som drivgas och sedan helium upp till 2.000.000 bilder/s.
3. En rubin pulslaser för studium av ytvågors utbredning i bergblock som användes med dubbelblixt teknik för att ge alla tre förskjutningskomponenterna. Kostnad ca 4.000\$.

De resultat som vi sett av institutionens arbete är mycket förtroendeingivande. En fortsatt kontakt bör vara av stort värde för båda parter.

Referenser

1. Persson, P.A. och
Johansson, C.H. Fragmentation Systems.-
Advances in Rock Mechanics,
Proc. ISRM:s 3:e kongress del
IB, sid 1557-1566, Denver 1974
(se även Stiftelsen Svensk Detonik-
forskning, rapport DS 1974:11).

2. Persson, P.A. och
Ouchterlony, F. Sönderbrytningssystem - en översikt.-
Stiftelsen Svensk Detonikforskning,
rapport DS 1975:1.

3. Lundborg, N. A Statistical Theory of the
Polyaxial Strength of Materials. -
som ref. I fast del IIA s 180-185.

4. Ouchterlony, F. Fracture Mechanics Applied to
Rock Blasting. -
som ref. I fast del IIB s 1377-1383.

5. Bjurström, S. Shear Strength of Hard Rock Joints
Reinforced by Grouted Untensioned
Bolts. -
som ref. I fast del IIB s 1194-1199.

6. Lundborg, N. Visit to the USA Sept. 1-21, 1974.
Stiftelsen Svensk Detonikforskning,
rapport DS 1974:16.

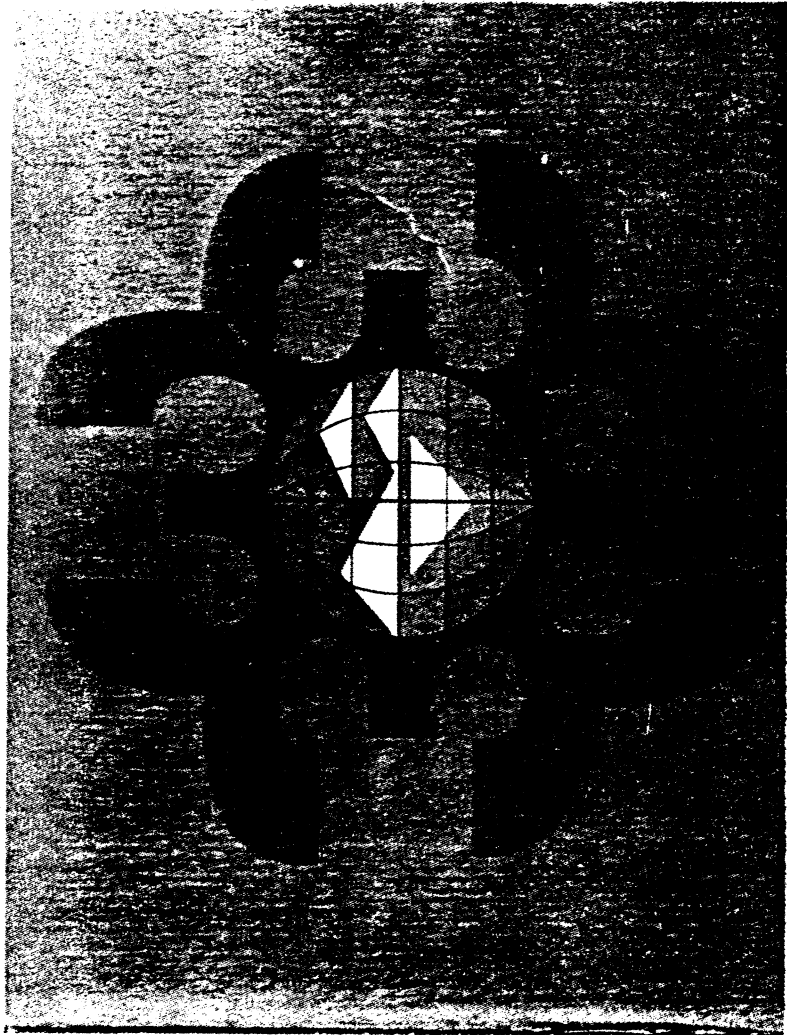
7. Bligh, T.P. Principles of Breaking Rock Using
High Pressure Gases. -
som ref. I fast del IIB s 1421-1427.

open room

INTERNATIONAL SOCIETY
FOR ROCK MECHANICS
3RD INTERNATIONAL CONGRESS

SOCIETE INTERNATIONALE
DE MECANIQUE DES ROCHES
3^{eme} CONGRES INTERNATIONAL

INTERNATIONALE GESELLSCHAFT
FUR FELSMCHANIK
3 INTERNATIONALER KONGRESS



1-7 SEPTEMBER, 1974 1-7. SEPTEMBER 1974 SEPTEMBRE 1-7, 1974
DENVER, COLORADO, USA
National Academy of Sciences National Academy of Engineering

MONDAY, SEPTEMBER 2, 1974 -- GRAND BALLROOM

09.00-10.00 Opening ceremonies: *G. B. Wallace*, Chairman
Welcome: *T. W. Ten Eyck*, Exec. Dir., Dept. of Natural Res., Denver, Colo.
Keynote address: *T. V. Fallick*, Director, U.S. Bureau of Mines
Introduction to Congress: *L. A. Ober*, President, International
Society for Rock Mechanics
Organizational details: *C. Fairhurst*

THEME 1: PHYSICAL PROPERTIES OF INTACT ROCK AND ROCK MASSES

- 10.15-12.00 Plenary Session -- Grand Ballroom
Chairman, *F. Patton*
- ✓ 10.15-10.45 Comments by General Reporter, *J. Bernatz*
- ✓ 10.45-11.45 Comments by Supplementary Reporters: *D. F. Coates*, *R. E. Goodman*,
K. W. John, *L. Müller*
- 11.45-12.00 Summary by General Reporter
- 12.00-14.00 Lunch
- 14.00-17.00 Discussion Session (part 1) -- Theme 1 -- Grand Ballroom
Chairman, *V. De Mele*, Co-Chairman, *W. Hawerzik*, Recording
Secretary, *H. S. Swolfs*
- 14.00-14.30 ✓ *P. Lokti*: "Discontinuity Anisotropy of Rock Masses" (Paper No. 1)
✓ *B. Kujundžić*: "Methods of Modelling in Engineering Geology and
✓ *Milovanović* Geo-Engineering" (Paper No. 2)
✓ *E. E. Qudava*, et al: "Weathering and Its Relation to Mechanical
✓ *Yoshinaka* Properties of Granite" (3)
✓ *Z. T. Bieniawski*: "Geomechanics Classification of Rock Masses
and Its Application in Tunneling" (4)
- 14.30-15.00 Informal discussion*
- 15.00-15.30 ✓ *B. A. Chappell*: "Numerical and Physical Experiments With Discontinua" (5)
✓ *N. Lundborg*: "A Statistical Theory of the Polyaxial Strength of
Materials" (6)
✓ *M. W. Kneal*: "The Energy Balance Theory and Rock Fracture Energy
Measurements for Uniaxial Tension" (7)
✓ *J. Bergues*, et al: "Plastic Deformation Microprocess of a Mineral
✓ *Habib* Crystallized Solid" (8)
(*M. M. Protodjakonov*): "Generalized Equations of Rheological Curves
for Rocks" (9)
- 15.30-16.00 Informal discussion
- 16.00-16.30 ✓ *N. Barton*: "Estimating the Shear Strength of Rock Joints" (10)
✓ *J. Farvan*, *R. Perami*: "Microfracturation, Deformation and Compres-
sibility of Rocks Under Triaxial Stresses" (11)
✓ *M. Montoto*: "Fatigue in Rocks: Failure and Internal Fracturation
of Barre Granite" (12)
✓ *M. John*: "Time-Dependence of Fracture Processes of Rock Materials" (13)
✓ *W. R. Hawerzik*: "Time-Dependent Behavior of Rock in Compression" (14)
- 16.30-17.00 Informal discussion
- 17.00 End of discussion session (to be continued Tuesday at 14.00)

*Time will not allow the use of slides or other audio-visual aids during the informal
discussion periods. Where such visual aids are considered essential, arrangements must
be made in advance with the Session Chairman.

TUESDAY, SEPTEMBER 3, 1974

THEME 2: TECTONOPHYSICS

- 09.00-11.00 Plenary Session -- Grand Ballroom
Chairman, C. B. Raleigh
- ✓ 09.00-09.30 Comments by General Reporter, A. Nur
Chairman, C. B. Raleigh
- ✓ 09.30-10.30 Comments by Supplementary Reporters:
(M. S. Faterson), C. B. Raleigh
- (10.30-10.45) Summary by General Reporter
- 10.45-11.00 Break
- 11.00-12.00 Discussion Session--Theme 2 -- Grand Ballroom
Chairman, B. Aizenstein, Co-Chairman, J. F. Mandin, Recording Secretary, D. Barber
- 11.00-11.30 ✓ J. D. Byerlee: "Acoustic Emission in Rock During Fluid Injection" (15)
- ✓ F. Rumel: "Changes in the P-Wave Velocity With Increasing Inelastic Deformation in Rock Specimens Under Compression" (16)
- ✓ E. S. Spry, W. F. Brace: "Some Permanent Structural Changes in Rocks Due to Pressure and Temperature" (17)
- ✓ W. D. Stuart, J. H. Dietrich: "Continuum Theory of Rock Dilatancy" (18)
- 11.30-12.00 Informal discussion
- 12.00-14.00 Lunch
- 14.00-17.00 Concurrent Discussion Sessions--Themes 1 and 2
Theme 1 -- Grand Ballroom
Theme 2 -- Junior Ballroom
(Details below)
- 14.00-17.00 Theme 1 -- Grand Ballroom
- 14.00-14.30 E. Durand, G. Comes: "The Torsional Test and The Shear Strength of Rocks" (19)
- ✓ E. T. Brown: "Fracture of Rock Under Uniform Biaxial Compression" (20)
- ✓ E. Broch: "The Influence of Water on Some Rock Properties" (21)
- ✓ G. Hergert, K. Uhrig: "In Situ Strength Prediction of Mine Pillars Based on Laboratory Tests" (22)
- 14.30-15.00 Informal discussion
- 15.00-15.30 ✓ F. Peres-Rodrigues: "Influence of the Scale Effect Over Rock Mass Safety Against Deformability" (23)
- ✓ H. R. Pratt, et al: "Friction and Deformation of Jointed Quartz Diorite" (24)
- N. N. Maslov, T. V. Pafishcheva: "Creep and Pseudocreep of Rocks and Their Effect When Estimating the Stability of Jointed Rock Masses" (25)
- ✓ C. Godfrey: "Dynamic Strength of In Situ Rock" (26)
- ✓ R. G. T. Lane, J. L. Krill: "Engineering Properties of Yielding Rock" (27)

- 15.30-16.00 Informal discussion
- 16.00-16.30 J. Bernade: "New Developments in the Flat Jack Test" (28)
- M. Rocha, et al: "A New Development of the INEC Stress Tensor Gauge" (29)
- D. Meister: "A New Ultra-Sonic Borehole-Meter for Measuring the Geotechnical Properties of Intact Rock" (30)
- K. Kovari, et al: "Displacement Measurements of High Accuracy in Underground Openings" (31)
- 16.30-17.00 Informal discussion
- 17.00 End of Theme 1 discussion
- 14.00-17.00 Theme 2 -- Junior Ballroom
- 14.00-14.30 F. H. Cornet, C. Fairhurst: "Influence of Pore Pressure on the Deformation Behavior of Saturated Rocks" (32)
- B. C. Haimson, et al: "Deep Stress Measurements in Tuff at the Nevada Test Site" (33)
- Z. G. Ter-Martirosyan, et al: "The Stressed State of Rock Masses in a Field of Body Forces" (34)
- I. A. Turchaninov, et al: "Complex Analysis and Experimental Determination of Complete Stress Tensor in the Rock Mass" (35)
- B. Voight, B. H. P. St. Pierre: "Stress History and Rock Stress" (36)
- 14.30-15.00 Informal discussion
- 15.00-15.30 D. W. Barber, B. M. Sawers: "A Photoelastic Study of the Effects of Surface Geometry on Fault Movements" (37)
- A. J. S. Bjornberg, et al: "Tectonophysical Aspects in Southeastern Brazil" (38)
- P. Habib, J. Quiblier: "Research on Natural Fracturing of a Petroleum Reservoir" (39)
- Y. Ohnishi, R. E. Goodman: "Results of Laboratory Tests on Water Pressure and Flow in Joints" (40)
- 15.30-17.00 General discussion
- 17.00 End of Theme 2 discussion
- WEDNESDAY, SEPTEMBER 4, 1974
- THEME 3: SURFACE WORKINGS
- 09.00-11.00 Plenary Session -- Grand Ballroom
Chairman, D. Misterek
- 09.00-09.30 Comments by General Reporters, E. Hoek/P. Londe
- 09.30-10.30 Comments by Supplementary Reporters: C. O. Branner, E. Fumagalli, V. Menal, M. Rocha
- 10.30-10.45 Closing remarks by General Reporters
- 10.45-11.00 Break

11.00-17.00

Discussion Session-Theme 3 -- Grand Ballroom

Chairman, B. Rajendran, Co-Chairman, L. B. Underwood, Recording Secretary, J. G. McClure

11.00-11.30 J. Bourbominia, N. R. Morganstern: "An Analysis of the Deformation of Three Dam Foundations" (41)

M. Hayashi, et al: "Dynamic Deformability and Viscosity of Rock Masses" (42)

A. Pellegrino: "Surface Footings on Soft Rocks" (43)

A. A. Serrano, E. Castillo: "A New Concept About the Stability of Rock Masses" (44)

11.30-12.00 Informal discussion

12.00-14.00 Lunch

14.00-14.30 D. C. Banks, W. E. Strohm: "Calculations of Rock Slide Velocities" (45)

N. Barton: "Rock Slope Performance as Revealed by a Physical Joint Model" (46)

M. P. Bello, M. F. Bello: "Localization of Old Slidings and Consequences for the Stability of New Projects" (47)

B. K. McMahon: "Design of Rock Slopes Against Sliding on Pre-existing Fractures" (48)

14.30-15.00 Informal discussion

15.00-15.30 Yu. A. Fishman, E. G. Garsiev: "In Situ and Model Studies of Rock Foundations Failure in Concrete Blocks Shear Tests" (49)

D. Milovanovic: "Some Observations Made in Model Tests in the Domain of Limiting Equilibrium of Dam Foundation Rock" (50)

M. Rocha, et al: "Application of Advanced Techniques to the Study of the Foundations of Sao Simao Dam" (51)

J. L. Serafim, M. Q. Guerreiro: "Tests and Observed Behaviour of Rock Foundations of Dams" (52)

15.30-17.00 General discussion

17.00 End of Theme 3 discussion

THURSDAY, SEPTEMBER 5, 1974

THEME 4: UNDERGROUND OPENINGS

09.00-11.00 Plenary Session -- Grand Ballroom
Chairman, T. A. Lang

✓ 09.00-09.30 Comments by General Reporter, M. D. G. Salamon

09.30-10.30 Comments by Supplementary Reporters: J. D. Dadekin, G. Everling, J. Geertsma, T. A. Lang, T. L. Fitts, G. Lombardi

10.30-10.45 Summary by General Reporter

10.45-11.00 Break

11.00-12.00

Discussion Session-Theme 4 -- Grand Ballroom
Chairman, A. Haryetadeu, Co-Chairman, D. Dahl, Recording Secretary, J. J. K. Duimen

11.00-11.30 ✓ D. F. Coates: "Probability of Pillar Failure at Elliot Lake" (53)

V. Y. Oka, Y. Hiramatsu: "The Behavior of Viscoelastic Rock Around Underground Openings With or Without Linings" (54)

V. S. G. Vick, H. H. Einstein: "A Probabilistic Approach to Geologic Investigations for Hard Rock Tunnels" (55)

✓ H. Wagner: "Determination of the Complete Load-Deformation Characteristics of Coal Pillars" (56)

11.30-12.00 Informal discussion

12.00 End of discussion session (to be continued Friday at 14.00)

FRIDAY, SEPTEMBER 6, 1974

THEME 5: FRAGMENTATION SYSTEMS

09.00-11.00 Plenary Session -- Grand Ballroom
Chairman, D. E. Fogelson

✓ 09.00-09.30 Comments by General Reporter, P. A. Persson

✓ 09.30-10.30 Comments by Supplementary Reporters: N. G. W. Cook, D. E. Fogelson, A. H. Khanikaveh, S. Takaoka, B. V. Vaitsekhovskii

10.30-10.45 Summary by General Reporter

10.45-11.00 Break

11.00-12.00

Discussion Session-Theme 5 -- Grand Ballroom
Chairman, A. Chaoi, Co-Chairman, W. C. Maurer, Recording Secretary, W. R. Heitner

11.00-11.30 ✓ B. Bhandari, V. S. Yutukuri: "Rock Fragmentation With Longitudinal Explosive Charges" (57)

✓ A. J. Hendron, C. H. Dowding: "Ground and Structural Response Due to Blasting" (58)

✓ C. H. Noren, D. D. Porter: "A Comparison of Theoretical Explosive Energy and Energy Measured Under Water With Measured Rock Fragmentation" (59)

✓ * F. Ouchterlony: "Fracture Mechanics Applied to Rock Blasting" (60)

11.30-12.00 Informal discussion

12.00-14.00 Lunch

14.00-17.00 Concurrent Discussion Sessions -- Themes 4 and 5
Theme 4 -- Grand Ballroom
Theme 5 -- Junior Ballroom
(Details below)

14.00-17.00 Theme 4 -- Grand Ballroom

14.00-14.30 M. M. DeJean, et al: "Strata Control Around Face Working" (61)

M. P. Hardy, et al: "A Hybrid Computer System for Simulating Inelastic Seam Behavior" (62)

- F. J. Molz, G. M. Hamberger:* "Digital Simulation of Regional Land Subsidence Due to Aquifer System Pumpage" (63)
- I. Sovine:* "Geotechnical Aspects of Longwall Face Caving" (64)
- 14.30-15.00 Informal discussion
- 15.00-15.30 *S. Bjurström:* "Shear Strength of Hard Rock Joints Reinforced by Grouted Untensioned Bolts" (65)
- V. L. Kubetsky:* "Investigation of Stresses in the Structure of a High-Pressure Tunnel Made by Grouting the Surrounding Rock Mass" (66)
- R. R. Thompson, et al:* "Pumpable Polymeric Rock Bolts" (67)
- B. N. Whittaker, et al:* "Support and Lining of Mine Roadways in the United Kingdom" (68)
- 15.30-16.00 Informal discussion
- 16.00-16.30 *J. A. Aramburu:* "La Angostura Dam Underground Powerhouse: Prediction and Measurement of Displacements During Excavation" (69)
- G. Brauner:* "Prevention of Rockbursts by Destressing Drilling" (70)
- E. Pfisterer, et al:* "Investigations, Calculations and Measurements for the Underground Powerhouse Wair" (71)
- M. Selimovic:* "Statistical Analysis of Percentage of Failed Rock for the Purpose of Selecting the Location of the Salakovac Diversion Tunnel" (72)
- 16.30-17.00 Informal discussion
- 17.00 End of Theme 4 discussion
- 14.00-17.00 Theme 5 -- Junior Ballroom
- 14.00-14.30 *R. T. Avery, et al:* "Use of Intense Sub-Microsecond Electron Bursts to Produce Rock Shattering" (73)
- ✓ *B. R. Jurewicz, et al:* "Rock-Kerfing With High-Power Lasers" (74)
- ✓ *J. C. Rowley:* "Rock Melting Applied to Excavation and Tunneling" (75)
- ✓ *K. Thirumalai, J. B. Cheung:* "Combined Thermal Energy Processes for Hard Rock Fragmentation" (76)
- 14.30-15.00 Informal discussion
- 15.00-15.30 *G. Comes:* "Driving by a Tunnelling Machine the Pressure Head-Garnier water Tunnel for a Hydroelectric Plant: - A Geomechanical Technical Analysis of the Problem" (77)
- ✓ *R. E. Jackson, et al:* "Chemical Enhancement of Rock Drilling" (78)
- ✓ *D. Jager, et al:* "Rock Properties and the Influence on the Use of Tunneling Machines" (79)
- ✓ *F. F. Roxborough, H. R. Phillips:* "Experimental Studies on the Excavation of Rock Using Picks" (80)
- 15.30-17.00 General discussion
- 17.00 End of Theme 5 discussion

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Appendix B: Diskussionsanteckningar från tema 5 - sönderbrytningssystem

Anteckningarna gäller först följande föredrag:

- (73) Avery: "Man projekterar nu en tunneldrivningsmaskin med elektronblixtaggregat med ca 100 pulser/s vilket kan ge en indrift på ca 16 m/dygn vid kontinuerlig drift."
- (74) Jurewicz: "Lasereffekten 16.5kW ger spårskärningshastigheten 125 cm/s men grunda spår. Man har gjort försök med kombinerad mekanisk och laserbrytning men har problem med det".
- (75) Rowley: "Svårsmälta bergarter är granit och andra kvartshaltiga bergarter liksom kalksten och höggradig kopparmalm".
- (76) Thirumalai: "Mekaniska brytningsmetoder applicerade på uppvärmda skut är mycket effektiva".

Under den diskussion som följde märktes inslag av

- (a) Schumacher vid Westinghouse: "Den kontinuerliga elektronstrålen är en fungerande bergbrytningsprincip. Jag är upprörd över den styvmoderliga behandling den fått vid denna kongress!"
- (b) Lundqvist vid Physics Int.: "Vårt REAM-project ger ett k-värde på ca $10\text{J}/\text{cm}^3$ medan borrar och sprängning ger ca $37\text{J}/\text{cm}^3$ vid tunneldrivning".

Sedan följde ytterligare två föredrag om sönderbrytning:

- (78) Swayne: "Resultaten från våra försök att borra snabbare med kemikalier i spolvätskan är temperaturoberoende i Westerley-graniten. Med 10 kp matningskraft på 2 tums skär vid 2800 slag/min nådde vi max. 2 cm/min i borrarjunkning".
- (79) Roxborough: "Det finns tryckfel i mitt bidrag (errata bifogas här). Vid den skärande bearbetningen använde vi Bunter-sandsten som innehåller ända upp till 90% kvarts. Spårlängden var 2 fot och vi använde nya hårdmetallskär varje gång. Underligt nog var våta stenar svårare att skära än torra. Detta gäller också i en annan sandsten som vi provat. Standardprov som exakt tryckhållfasthet ger ju motsatt resultat!"

Den avslutande diskussionen innehöll bidrag av:

- (c) Fransman från Toulouse: "Vi gör FF-forskning och studerar olika tänkbara brottmoders inverkan på avverkningshastigheten. Krossningsmoden testas vi med s.k. discutters men det går dåligt

korrelation till FF-resultat. Friktionsmoden testas vi med diamantkärnbörning vilket ger god korrelation för gneiss. Flisbildningsmoden är under studium".

- (d) Atchison vid US BuMines: "Warren Krechs arbete på Rock Fracture Energy, som redovisades i föredrag (7) under tema I, ger bättre korrelation med en bergarts skärbarhet än tryckhållfastheten uttryckt i kp/cm^2 ".
- (e) Evans vid Natl. Coal Board: "I Europa är det allmänt känt att det är effektivare att skära djupa spår vid avverkning av kol, men det är det tydligen inte i USA".
- (f) Schumacher (igen): "Den kontinuerliga elektronstrålen är bättre än elektronblixmetoden (73). I den sistnämnda kommer man att få problem med röntgenstrålning p.g.a. MV-spänningar i drivsystemet och med energilagringen i kondensatorbatterierna. Dessutom behöver den kontinuerliga strålen inte gå genom ett skyddsfönster vilket blixarna gör".
- (g) Avery: "Elektronblixmetodens stora fördel är att den orsakar mekaniskt utstötningsbrott i bergytan vilket ger betydligt lägre k-värde än den kontinuerliga strålen ger, som avverkar genom förångning av berget".
- (h) Grälartat meningsutbyte mellan Schumacher och Jurewicz.

FRANK F. ROXBOROUGH & HUW R. PHILLIPS, (Dept. of Mining Engineering,
University of Newcastle upon Tyne, England)

EXPERIMENTAL STUDIES ON THE EXCAVATION OF ROCK USING PICKS.

ERRATA

Correct tables 3, 4 and 5 to read

TABLE 3 - UNRELIEVED CUTTING CONSTANTS

	$\bar{F}_c$	F_c	$\bar{F}_n$	F_n		Q		S.E.
A ($\times 10^{-6}$)	8	19	40	53	G	31.5	J	3.0
B ($\times 10^{-2}$)	10.6	22.8	7.0	31.9	H ($\times 10^{-5}$)	13.6	K	509
C	30	35	15	35	I ($\times 10^{-3}$)	59.4	L	30
E	19.2	34.5	6.9	12.9			M	2.0
							N	2.0

TABLE 4 - RELIEVED CUTTING CONSTANTS

	$\bar{F}_c$	F_c	$\bar{F}_n$	F_n		Q		S.E.
A ¹ ($\times 10^{-3}$)	5.1	9.2	5.5	11.0	I ¹ ($\times 10^{-3}$)	1.8	N ¹ ($\times 10^{-6}$)	86.1
B ¹ ($\times 10^{-2}$)	5.7	6.8	4.3	9.6	J ¹ ($\times 10^{-2}$)	1.5	P ¹ ($\times 10^{-6}$)	60.8
C ¹	20	10	10	10	K ¹	10	R ¹	1.01
E ¹	17.4	18.1	17.3	15.5	L ¹	1.5	T ¹	19.0
G ¹	15	15	15	15	M ¹	35.5	U ¹	15.0
H ¹	6.5	11.5	2.5	6.1			V ¹	10.5
							X ¹	5.0
							Y ¹	12.6

TABLE 5 - PREDICTED AND MEASURED VALUES FOR
UNRELIEVED CUTTING IN BUNTER

Parameter	Predicted	Measured ($\pm$ s.d.)	Difference ($\times$ s.d.)
$\bar{F}_c$ (kN)	0.65	0.57 $\pm$ 0.09	+ 0.9 s.d.
$\bar{F}_n$ (kN)	0.49	0.64 $\pm$ 0.11	- 1.4 s.d.
F_c (kN)	1.72	1.54 $\pm$ 0.11	+ 1.6 s.d.
F_n (kN)	1.25	1.29 $\pm$ 0.11	- 0.3 s.d.
Q (kg/m)	0.28	0.31 $\pm$ 0.06	- 0.5 s.d.
S.E. (MJ/m ³)	4.70	3.80 $\pm$ 0.79	+ 1.1 s.d.

Soil and Rock Instruments

EXTENSOMETERS AND STRAIN GAUGES

- multiple rod extensometer
- 2-point rod extensometer
- telescopic tube extensometer
- magnet-probe extensometer
- potentiometric extensometer
- vibrating wire embedded strain gauges
- vibrating wire surface mounted strain gauges

INCLINOMETERS

- probe inclinometer
- combined inclinometer/extensometer
- fixed electrolevel clinometer
- optical deflectometer
- inverted and hanging pendula

SETTLEMENT GAUGES

- hydraulic settlement gauge
- mercury settlement gauge
- multiple and single rod extensometers
- USBR tape settlement gauge
- inductance settlement probe
- magnet-probe extensometer
- pneumatic settlement cell
- hydraulic/magnetic vertical and horizontal movement probe
- survey bench marks and datum points

CONVERGENCE

- tape convergence meter
- micrometer rod gauge

CRACK MONITORING

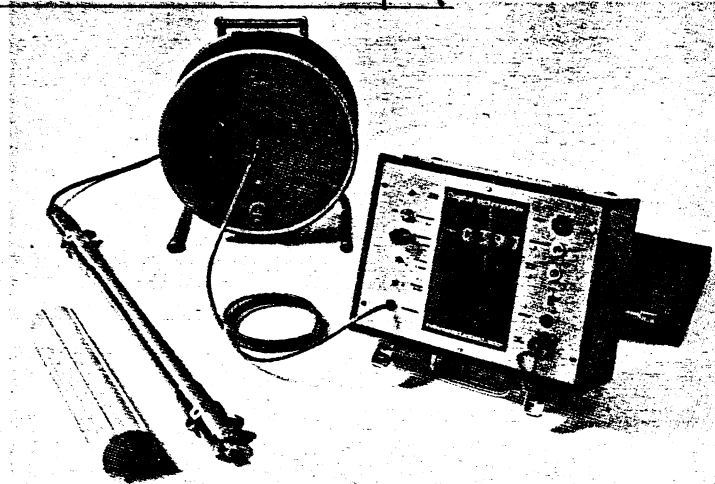
- portable crack gauge
- portable clinometer
- surface mounted rod extensometer

WATER

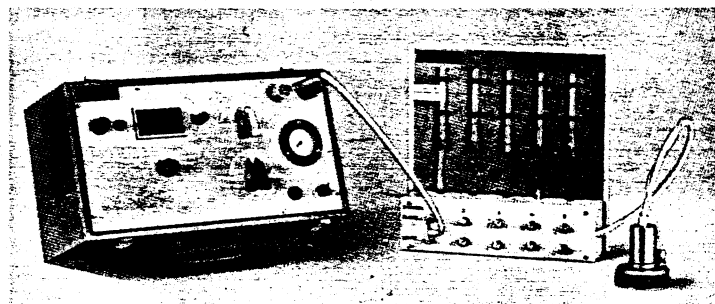
- standpipe and water level probe
- hydraulic twin tube piezometers
- pneumatic piezometers
- electric piezometers
- push-in and drive-in designs
- porous tips in high/low air entry ceramic and plastic
- automatic scanning and recording
- manometer, bourdon gauge or transducer readout
- water sampler

LOAD AND PRESSURE

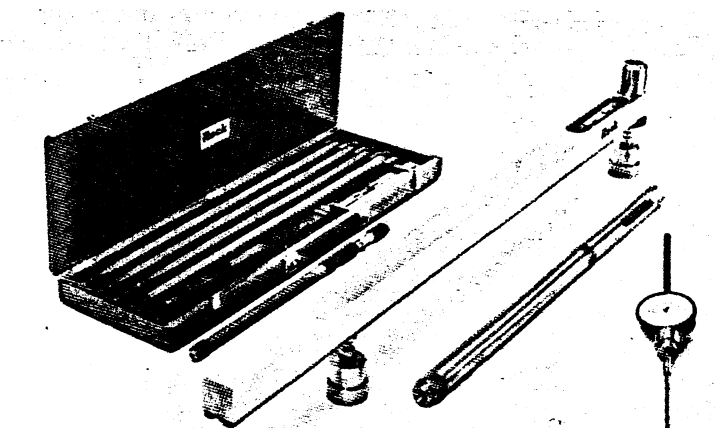
- vibrating wire load cells
- strain gauge load cells
- solid and centre hole designs
- oil-pneumatic pressure cells
- mercury-oil pressure cells
- vibrating wire pressure cells
- strain gauge pressure cells



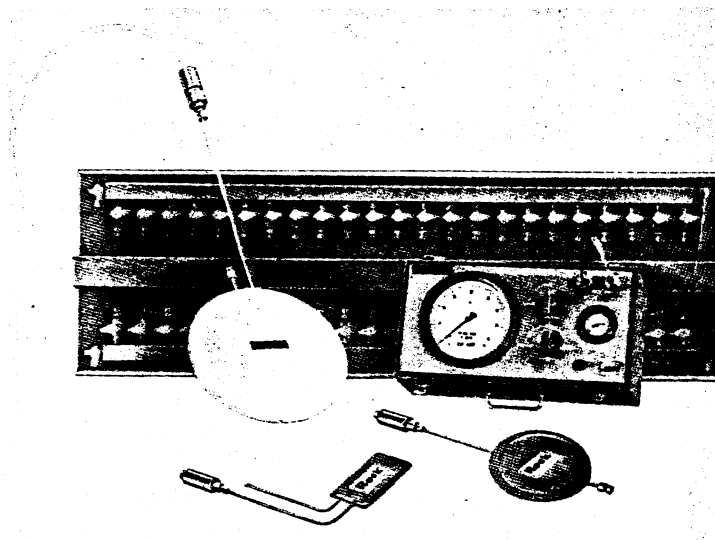
INCLINOMETER TORPEDO WITH DIGITAL READ-OUT



PNEUMATIC SETTLEMENT CELL WITH DIGITAL READ-OUT



PORTABLE CLINOMETER AND EXTENSOMETERS



OIL-PNEUMATIC PRESSURE CELL WITH READ-OUT EQUIPMENT

SOIL INSTRUMENTS LIMITED,

ROCK INSTRUMENTS LIMITED,

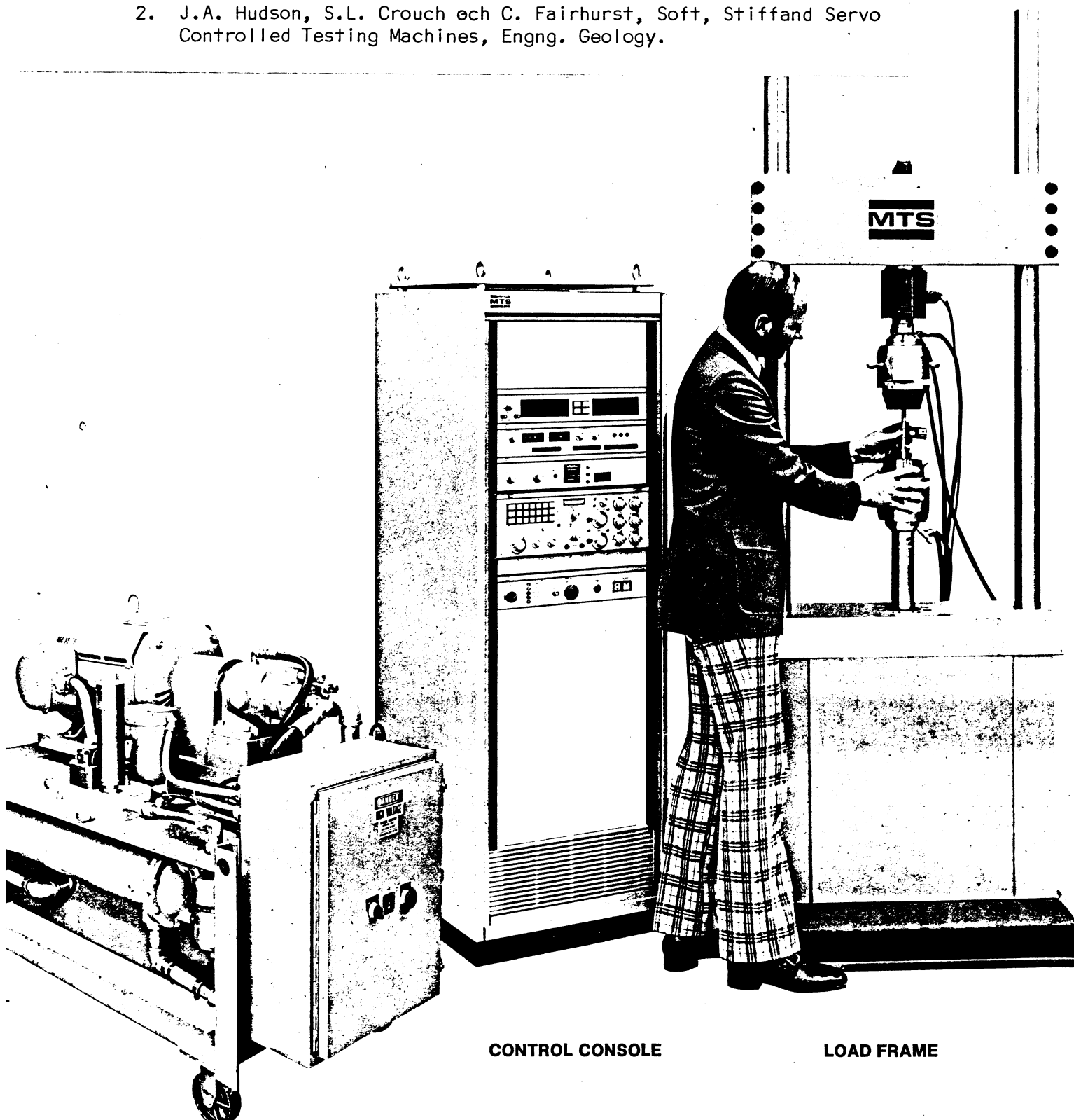
Townsend Lane, London, NW9 8TR

Telephone: 01-200 0633. Cables: SOLINST LONDON NW9.
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SERVOSTYRDA PROVNINGSMASKINER

Litteratur:

1. H.R. Hardy, R. Stefanko och E.J. Kimble, An Automated Test Facility for Rock Mechanics Research, Int. J. Rock Mech. Sci. vol8; 17-28 (1971).
2. J.A. Hudson, S.L. Crouch och C. Fairhurst, Soft, Stiff and Servo Controlled Testing Machines, Engng. Geology.



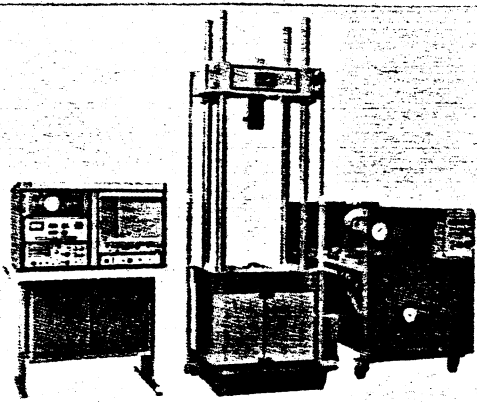
CONTROL CONSOLE

LOAD FRAME

HYDRAULIC POWER SUPPLY

Materials Testing

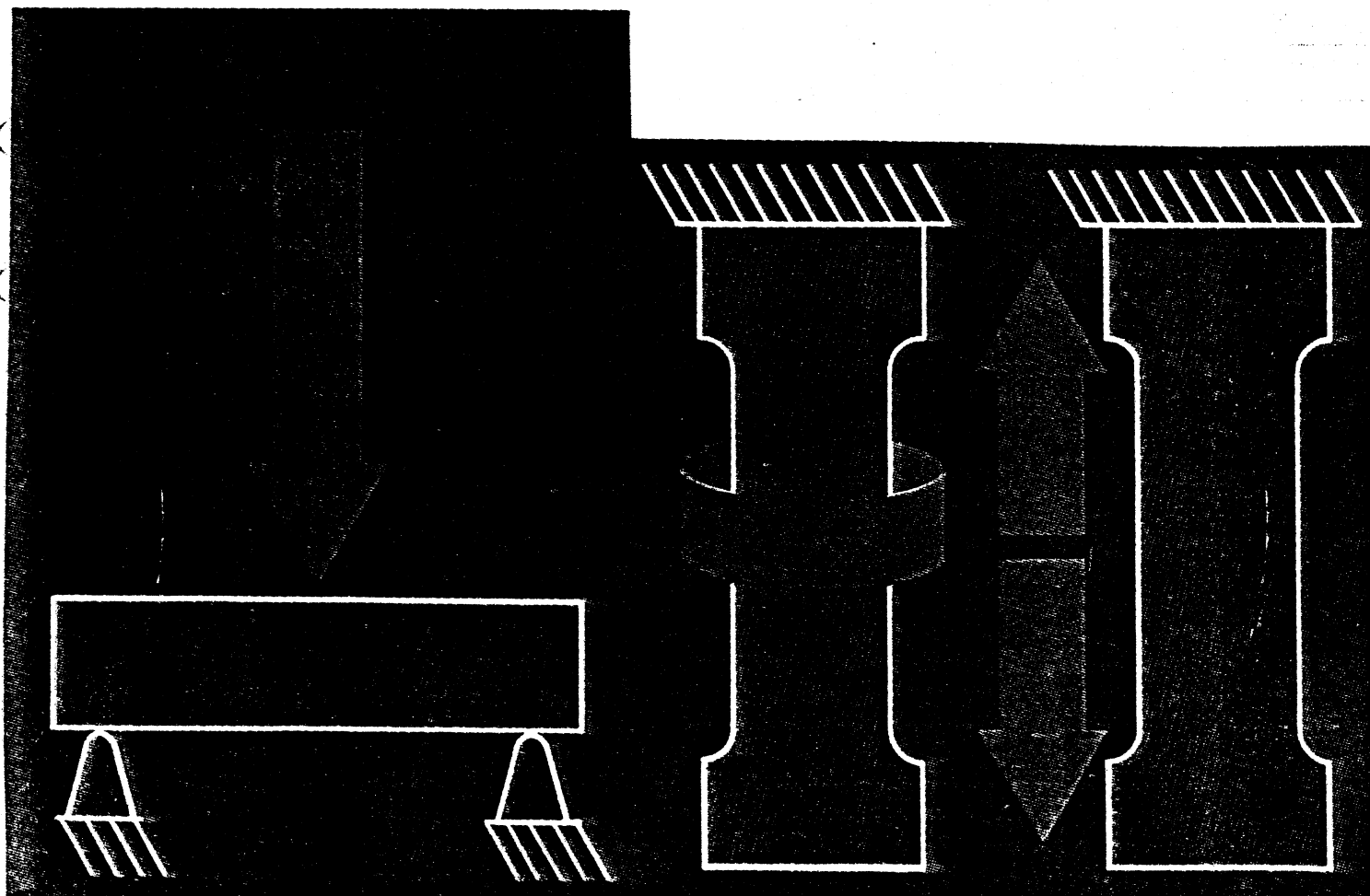
MTS materials testing systems are versatile. A basic test system can be used — without modification — for a wide variety of test programs and test materials. MTS systems can also be individually tailored to a very special testing requirement or a specific user requirement. Because all MTS systems use the modular concept, additional capabilities can be added later, preserving the customer's initial investment. For example, our Data/Control Processor may be added to continuously control and calculate test parameters, acquire data, and print out test results.



This typical MTS materials testing system features third-generation electronics for control of load, stroke or strain parameters. A variety of grips, bending fixtures, and extensometers is available.

Applications

- Conventional stress-strain relationships; tension and/or compression testing
- High strain rate testing in tension or compression
- Short or long term creep testing
- Fatigue testing — constant amplitude; programmed amplitude; mean level and/or frequency; and random amplitude/frequency
- Low cycle fatigue testing — including plastic strain applications for strain hardening studies
- Elastomer testing — a specifically-designed system is available for determining the K and C values of elastomer materials
- Crack propagation studies in stress corrosion or fatigue. Control of loads with crack length (e.g. constant K tests)
- Fracture mechanics studies, with fatigue pre cycling and pull test performed with the same machine
- Testing in other modes (e.g. bending, torsion) using suitable fixtures
- Rock mechanics testing
- Soil mechanics testing
- Bi-axial and tri-axial testing



METRIC

SYSTEM SPECIFICATIONS

Maximum Load ($\pm$ Tons-force) ($\pm$ SI-kN)	5 50	10 100	25 250	50 500	100 1000	250 2500
System Model No.	810.11M	810.12M	810.13M	810.14M	810.15M	810.16M
Full Scale Load Ranges ($\pm$ Tons-force) (Tension-Compression)	5,2.5,1, 0.5	10,5,2, 1	25,10,5, 2.5	50,25,10, 5	100,50, 20,10	250,100, 50,25
Full Scale Displacement Ranges ($\pm$ Millimeters)	100,50, 20,10	100,50, 20,10	100,50, 20,10	100,50, 20,10	100,50, 20,10	100,50, 20,10
Nominal Test Speed Range (mm/min.)	0-3800	0-1800	0-2600	0-1250	0-1250	0-850

LOAD FRAME DATA

Force Rating ($\pm$ Tons-force) ($\pm$ SI-kN)	5 50	10 100	25 250	50 500	100 1000	250 2500
Load Frame Configuration	2-column	2-column	2-column	2-column	4-column	4-column
Maximum Test Opening (width x height) (mm)	533 x 1118	533 x 1118	635 x 3975	762 x 2057	591 x 1948	762 x 2108
Load Frame Stiffness (kg/mm)	2×10^4	2.1×10^4	4.1×10^4	6.8×10^4	18×10^4	36×10^4
Max. Displacement of Actuator (mm)	150	150	150	150	150	150
Maximum Frequency** At Full Load — Displacement Control — Hz	25	12	14	6	7	5
Maximum Frequency** At 50% Load — Displacement Control — Hz	50	22	23	11	12	8
Height (mm)	2440	2440	3040	3660	3660	3660
Shipping Weight (kg)	450	450	910	1815	4100	10,000

HYDRAULIC POWER SUPPLY DATA

Flow at 210 kg/cm ² (l/m)	10	10	32	32	62	115
Water Required — Maximum Demand at 24°C, 2,8 kg/cm ² (l/m)	13	13	23	23	23	65
Power Required — Maximum Demand at 380 volt/50 Hz/3 phase (amps)	9	9	33	33	55	95
Motor Horsepower Rating — HP	7.5	7.5	20	20	40	75
Dimensions (H x W x D) mm	1270 x 600 x 690	1270 x 600 x 690	1000 x 825 x 1244	1000 x 825 x 1244	1400 x 1000 x 1700	1500 x 1000 x 1715
Shipping Weight (kg)	160	160	865	865	1350	1800

CONTROL CONSOLE DATA (ALL MODELS)

Power Required	10 amp @ 220VAC
Add-On Equipment Space (height in 48mm rack)	178mm
Dimensions (L x W x H)	1550 x 1220 x 864mm
Shipping Weight	270 kg

*1 Kip = 1,000 lbs. — force

**Compliance of specimen and grips assumed to be 0.25mm single amplitude.

Fam Ou ZFC

REMOTE SENSING OF HAZARDOUS CONDITIONS IN UNDERGROUND MINES

DENVER MINING RESEARCH CENTER

BY Raymond M. Stateham, Geophysicist, Special Studies Group
Bldg. 20, Denver Federal Center, Denver, Colorado 80225

The U. S. Bureau of Mines, as a part of its Health and Safety research program, is developing instruments and techniques for detecting and locating hazardous conditions in underground mines. Theoretical and field studies conducted by the Denver Mining Research Center indicate that infrared devices can be used for this purpose.

The primary objective of these investigations has been the detection of loose, hazardous rock by means of temperature differences between the surface of loose rock and adjacent solid rock; such differences will exist, provided a contrast in temperature exists between the mine air and the surface of the rock. Because the fracture behind the loose rock interferes with heat transfer between the loose rock and the rock mass, the loose rock is slightly different in temperature from the surrounding solid rock surface. Field studies have shown that these temperature anomalies are from 0.2 to 0.5 degC in most mines. Consequently, remote sensing thermal devices such as infrared imagers, can detect and identify loose rock from safe locations.

Other field investigations show that the same equipment can be used to detect unconscious miners, faulty electrical conditions, fires, hot bearings, or any other hazardous or undesirable conditions that generate hot or cold contrasts.

As a part of these studies, the Bureau of Mines, through contracts and cooperation with the U. S. Army's Night Vision Laboratory, has developed a small, portable infrared imager which can be used underground. More advanced instruments are now in development which will be permissible for use in underground coal or gassy mines. The progress to date on thermal imaging devices is encouraging, but the state-of-the-art in infrared technology has produced equipment that has borderline sensitivities for this task, especially the detection of loose rock.

Other contracted investigations were made with the Colorado School of Mines to determine whether or not temperature gradients exist in underground mines. This research produced evidence that temperature gradients exist in coal near working faces, and the differences are usually greater than 2 degC at a depth of 2 feet. Therefore, new temperature environments can be expected in active faces because the machine or conventional mining techniques expose new surfaces well beyond 2 feet.

Present work has expanded into metal and nonmetal mines, and research is underway to produce or enhance temperature differences and to determine whether or not continuous, loose layers can be detected by remote sensing.

Film On ZFC

The Time Domain Reflectometer System
Used to Detect Ground Movement due to Mining

In mining research, inexpensive and easily installed devices are needed to monitor ground movement caused by mining. Coaxial cables and TDR equipment is one such device.

The TDR unit works on the pulse-echo testing technique. This technique is sometimes referred to as "radar testing." A pulse (called the incident pulse) is sent down the cable, traveling until it reaches an impedance discontinuity, (i.e. a change of impedance due to a break, short, termination, etc.). At the discontinuity a portion of the pulse is reflected back to the beginning of the cable. The rate of travel (propagation velocity) through a cable is constant. The distance from the beginning of the cable to the discontinuity can be calculated by measuring the time between the start of the pulse and the reflected signal.

The field work begins with the installation of a coaxial or series of coaxial cables being grouted into small diameter holes, preferably diamond core drilled holes. The core will help to tell what the hole geology is and hence what areas of the cable to watch for signs of movement.

The best coaxial cable to use is a solid aluminum jacketed type with an outer protective plastic jacket with a 50 ohm impedance. Under most field conditions, a 1/2 inch outside diameter cable has proven to be the most easily handled by field personnel during installation.

The cable should be premarked at regular intervals, then dented at these marks as it is fed into the hole. These dents increase the accuracy of locating movement areas along the cable when looking at the strip charts.

After the cable is grouted, you are ready to monitor it. The cable is monitored with a unit such as the unit shown. The unit is self-contained with a strip chart output for permanent records. The strip charts provide a "fingerprint of the condition of the cable." By comparing strip charts, you can see where and when movement is occurring.

Nikki J. French

BUILDING 20
DENVER FEDERAL CENTER
DENVER, COLORADO 80223

File On ZFC

COAL BUMP MONITOR
U. S. Bureau of Mines
Denver Mining Research Center
Denver, Colorado 80225

The Coal Bump Monitoring system, Figure 1, monitors low level seismic activity often referred to as microseismic noise. Microseismic noise is generated in a mine structure as the structure is stressed (forced to bear additional weight) by removal of ore during the mining operation. When such microseismic noises occur and are detected by four or more vibration sensitive geophones placed in an array in the mine workings, the signals can be fed to a computer which calculates the source of each microseismic noise and prints this information on a teletype.

The majority of rock noises released from a mine structure originate from the areas most actively adjusting to the changing stress conditions caused by mining. These areas are usually either local to the active mining, from major geological features, or most importantly, from areas prone to failure. Thus, by plotting the source location of each rock noise relative to a mine structure, one can delineate the areas that are most effected by changing stress conditions. Also, by plotting the rate at which rock noises occur from each area, one can estimate the stability of each area.

These methods have been used in a coal mine in Western Colorado to examine the mechanics of the bounce type of coal mine failure. The emphasis to date has been to determine if coal mine bounce areas can be delineated prior to failure and to determine if the stability of bounce-prone areas can be estimated. To date, in hindsight, one bounce area was shown to be delineable weeks in advance of failure and noise plots indicated that failure was likely. These results are most promising, and work continues to prove the reliability of these methods and gain the experience necessary to delineate these areas on a daily basis in advance of failure.

A similar approach was very successful in examining the rock burst type of failure, a failure very much like coal mine bounces, and resulted in methods now in practice to help control these failures.

ROCK BURST MONITOR

U. S. Bureau of Mines
Denver Mining Research Center
February 8-10, 1973

The Rock Burst Monitoring system used in conjunction with the Bureau of Mines, Denver Mining Research Center, convention display has been developed into a very useful engineering tool for the control of rock bursts. Rock bursts occur because high horizontal stresses that increase with depth are encountered at many relatively deep mines. These high stresses are borne by an increasingly smaller area as ore is removed. When the remaining ore pillar reaches a critical size at which it can bear no more load, it fails violently often causing injuries to mine personnel and serious damage to mine workings. This violent failure is called a rock burst. Rock bursts are sometimes mistakenly referred to as air bursts because of the accompanying rush of air pushed and compressed by the exploding rock.

The Rock Burst Monitoring system, illustrated in Figure 1, monitors low level seismic activity often referred to as microseismic noise. Microseismic noise is generated by the mine rock as it is stressed (forced to bear additional weight) by removal of ore during the mining operation. When such microseismic noises occur and are detected by four or more vibration sensitive geophones placed in an array in the mine workings, the signals are fed to a computer which uses the differences in the microseismic arrival times to calculate the source of the microseismic noise and then prints this information on a teletype. The microseismic noises are normally generated far in advance of violent failure. Thus the origin of the noises coupled with the rate (number)

15

of noises can be used by the rock mechanics engineer to determine the location of burst prone areas and plan destressing of such areas where necessary.

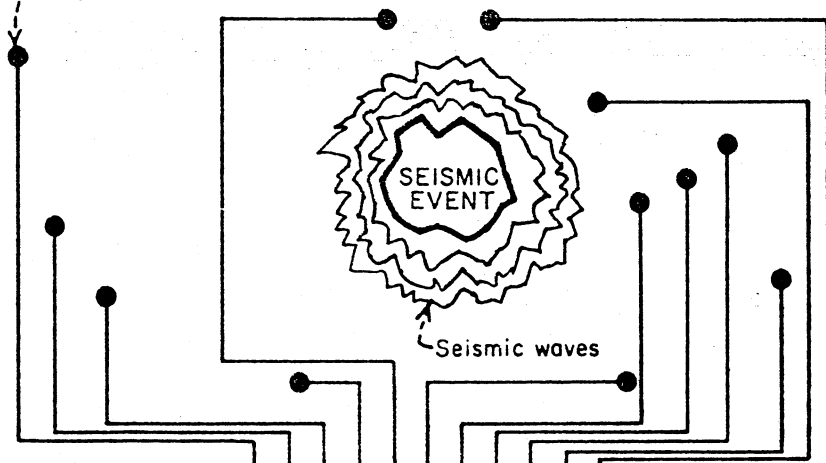
Destressing is a process in which stress is shifted from the ore pillar to the surrounding rock. Explosive charges are placed in drill holes which are spaced across the high stress areas of the ore pillar in such a manner that the ore pillar is cracked but not shattered. Effectively the modulus of the pillar rock is lowered so the high stress is carried by surrounding rock and a potential rock burst may be reduced or prevented.

The exhibit before you portrays a mine with an array of geophones. If a point on the plastic display is tapped, to simulate a microseismic noise produced by a change in stress, the geophones will pick up the signal, feed it to the computer and the location of where the plastic display was tapped will be recorded on the teletype.

This system is now in operation at one of industry's deep underground mines and is performing as designed.

U. S. BUREAU OF MINES DENVER MINING RESEARCH CENTER

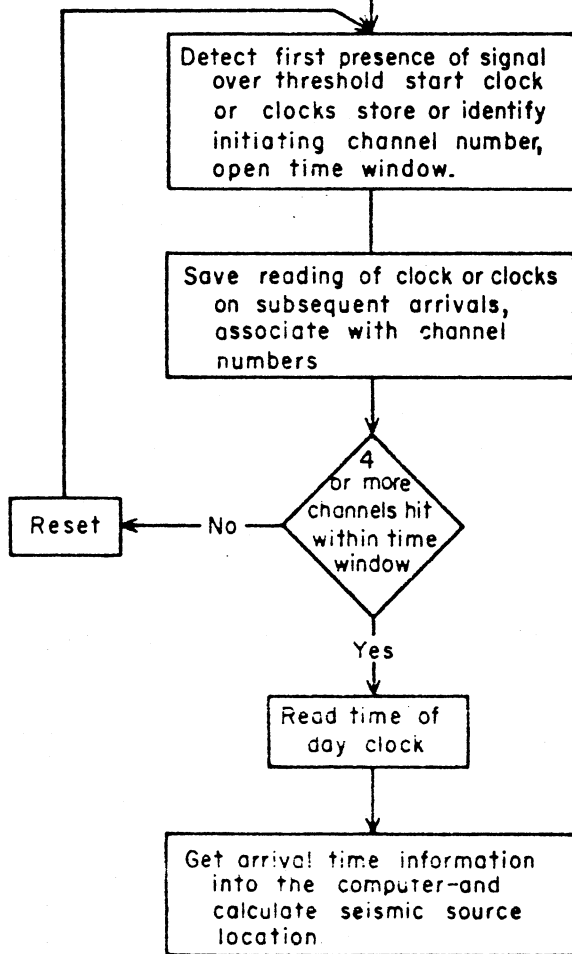
Geophone transducers at various known coordinates in the workings



System signal conditioning
and acquisition

Analog seismic
wave signals

INTERFACING



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4. Blake, Wilson. An Automatic Rock Burst Monitor for Mine Use. Proceedings Conference on the Underground Mining Environment, Univ. of Missouri at Rolla, Oct. 25-27, 1971, pp. 69-82.
5. Blake, Wilson. Rock Burst Mechanics. Quarterly of the Colorado School of Mines, v. 67, No. 1, 1972, 64 pp.

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Fording Coal Operation (Cominco)

P. J. Urso - Manager
Tony Austin - Planning Engineer - Tour Guide
Colin McKenny - Geologist - Tour Guide

Production - 3 million tons per year
Size Shipped - $\frac{1}{4}$ "
Unit Train - 10,000 ton
Unit Train Cycle Time - 72 hours
Shipped To - Japan
Coal Price - \$33/ton FOB Vancouver
Number of Employees (Staff & Labor) - 600

Stripping Ratio - $5\frac{1}{2}:1$ (cubic yards)
Overburden - shale, mudstone, siltstone

Multiple Seam (Truck & Shovel Operation)

Shovel - Bucyrus Erie 280B
Shovel Productivity - 6000 yd.³/shift
Trucks - 22 WABCO 150 ton
Truck Capacity - 65 cubic/yards
Truck Operating Cost - \$40 to \$60 per hour

Single Seam (Dragline?)

Thickness - 50 feet
% Volatile - 20
Dragline - Marion 8400
Bucket Capacity - 65 cubic yards
Boom Length - 300 feet
Digging Depth - 200 feet
Cast Distance - 200 feet
Dragline Operating Cost - \$120 to \$150 per hour
12000 yd³/shift

Drills

45R - 9 7/8" hole
60R - 12 1/4" hole
Drill Hole Pattern - 23' x 30'
Sub Grade Drilling - 10' to 15'
Bench Height - 33' (changing to 40')
Powder Factor (ANFO) - 0.6 #/yd.³

Fording Coal Operation-kompletterande uppgifter

Gruvan ägs av Canpac Mining till 60% och av Cominco som driver den till 40%. Investeringarna i gruvan överstiger 150M\$. Man har ett 15 års kontrakt med Japan av vilka 11 år återstår. Priset diskuteras en gång i halvåret. Kolet är högvärdigt utan svavel eller fosfor och lämpar sig för koksning.

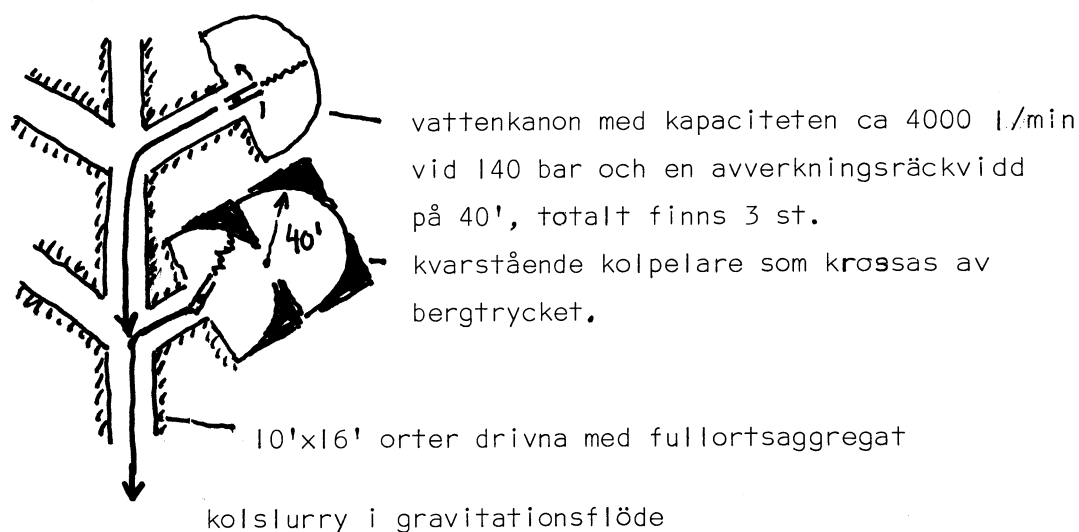
I dagbrottsdelen ligger 14-15 flötsar i lager vardera ungefär 17 m höga. Man har vissa problem med ras i slagghögarna som är upp till 600 m höga. Rasen hålls under kontroll med wire-deformationsmätningar mellan slänt och fast mark. En sättning om 0.05"/dygn betraktas som normal medan 0.25-0.30"/dygn ofelbart lett till ras inom ett par dagar. Släntvinkeln varierar mellan 33-34° vid foten och 38° vid krönet. Efter färdigbrytningen ställer statliga bestämmelser krav på 28° släntvinkel och skogsplantering på området.

Man har en "powder-factor" på 0.6-0.75 ounces /yd³ och använder mest ANFO med 5" slurryprimer. I blöta hål använder man Al-slurry.

Gruvan körs 24 tim/dygn i tre skift. Man har svårt att få tag på borrare och andra tekniker med erfarenhet. Bl.a. därför arbetar många gruvarbetarhustrur redan i verkstaden och några kör kanske redan om två är de tunga truckarna. Arbetarna tjänar 4.60-5.10 \$/h. Högst lön av arbetarna hade "dragline"-operatören. Den var 7.50 \$/h.

Kaiser Corporations kolgruva med hydrauldrift i Elkford

Skiss efter andrahands uppgifter:



Vårdar: Ken Bradley, planeringsingenjör - Jerry Sanford, geolog -
Howard Jeman, ingenjör och James Johnstone, överingenjör.

CRAIGMONT MINES LIMITED
MERRITT, BRITISH COLUMBIA.

The Craigmont property is situated in south-central British Columbia about 10 miles northwest of the Town of Merritt and about 120 miles north-east of Vancouver; latitude 50°12'23" N and longitude 120°54'48" W. Access to the property is by paved road which connects with No. 8 Highway at Lower Nicola and the Canadian Pacific Railway at Coyle.

Moderate local relief ranges from 1850 elevation at the Nicola River, 2400 elevation at the plant site, and 4450 elevation at the west end of the open pit area to 5600 elevation at the top of Promontory Hill. The Nicola River and Guichon Creek are the main drainages in the area and occupy broad valleys. Vegetation and climate are typical of the semi-arid "dry belt" of British Columbia with annual precipitation of approximately 14 inches. Much of the valley bottoms are open and covered with sagebrush. The upper slopes have more rainfall and hence a denser forest cover. Temperature ranges from 20 degrees below zero in winter to 100 degrees above in summer.

The chalcopyrite magnetite-specularite orebodies have a combined strike length of approximately 2,800 feet and extend over a vertical distance of 2,000 feet. Ore reserves at 1st November 1967 were 20,700,000 tons grading 1.72% copper. The orebodies lie in steeply south-dipping Triassic Nicola Group rocks which parallel the east-west contact of the south end of the Jurassic Guichon batholith. In the vicinity of the mine, outcrop exposure is about 10 percent. None of the orebodies were exposed at surface but were covered by either a thin layer of glacial till or Cretaceous Kingsvale Volcanic rocks.

In early 1965, it was decided to change over the underground mine to the Sub-Level Caving method of mining. Limited production commenced in September, 1967 from the Wing Orebody and full production was attained in mid 1968.

Current production is coming from the Number 2 Wing and the Number 1 Main Orebodies. Scheduled tonnage from the underground mine is 90,000 tons per month. This total is comprised of 80,000 tons of production and 10,000 tons of development ore. The proportion of production to development ore fluctuates from one month to another.

Presently, mining and development are being concentrated above the 3060 Level.

Blasted ore is extracted from production headings using diesel powered, trackless, load-haul equipment and is dumped into an orepass system. The orepass system connects with 2400 Level which serves as the main haulage for the mine. Ore is transported on the 2400 Level by train from the orepasses to a primary crusher located on the surface.

A normal ore train consists of twelve, 256 cubic feet Granby type cars pulled by a 25 ton trolley locomotive.

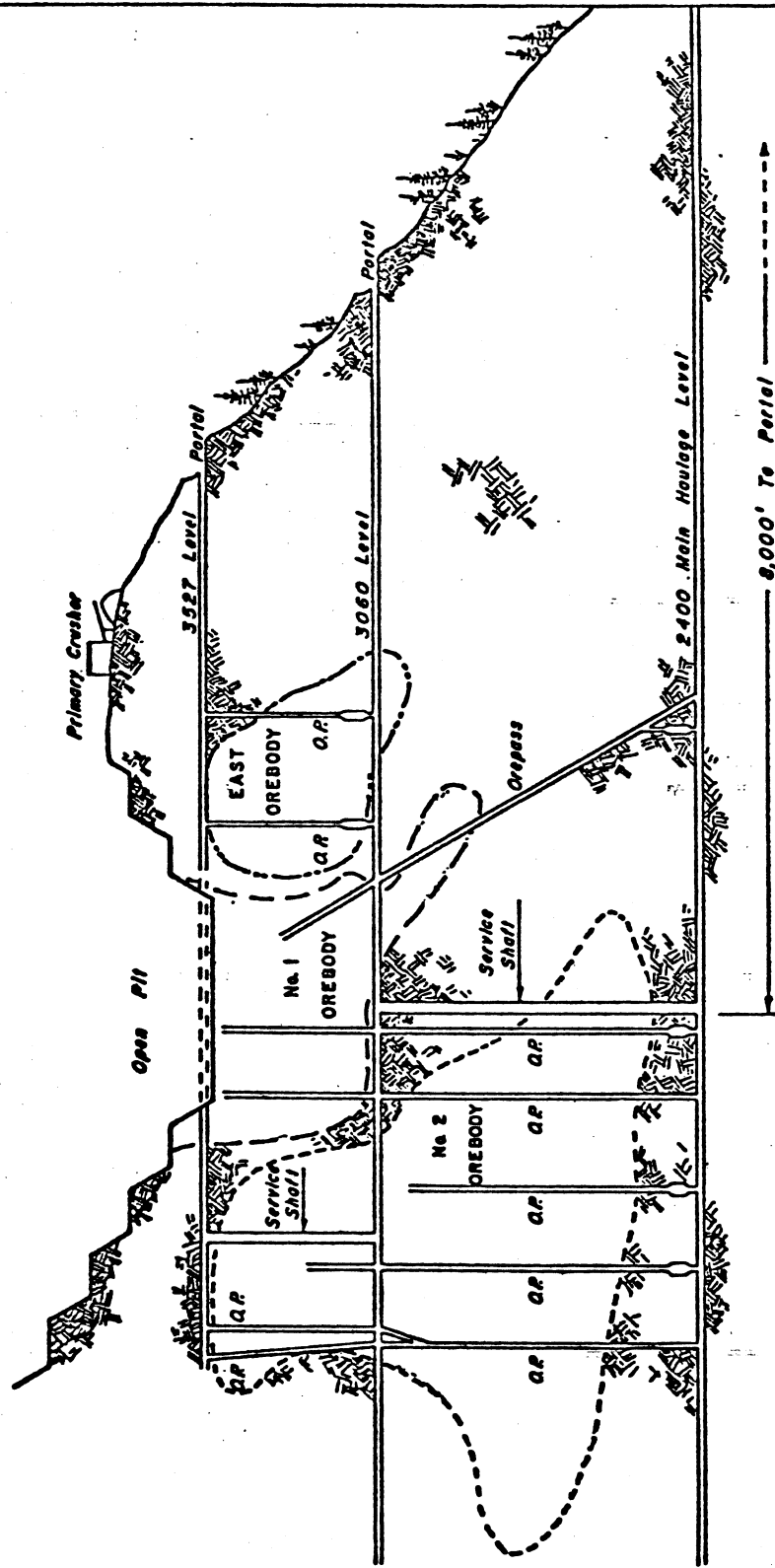
Fresh air enters the mine via the 2400 and 3060 adits for distribution throughout the mine workings. Spent air is collected by a system of ventilation raises and drifts and is exhausted through the 3060 ventilation adit by a 73 inch vaneaxial fan. Volume is about 180,000 c.f.m. at 7½

CHOICE OF EQUIPMENT

An important decision that had to be made at once was the choice between using large diesel equipment or small air equipment. Large equipment offered high productivity, and the minimum number of orepasses, but high drift maintenance, high mechanical maintenance and high ventilation requirements as compared to air equipment. Due to the bad ground conditions, installation and maintenance of orepasses are high cost items; due to this factor and the advent of shotcreting we decided to go to the larger openings and equipment. We now have four ST4's and four ST5's - ST4 units are being converted as engine changes become necessary.

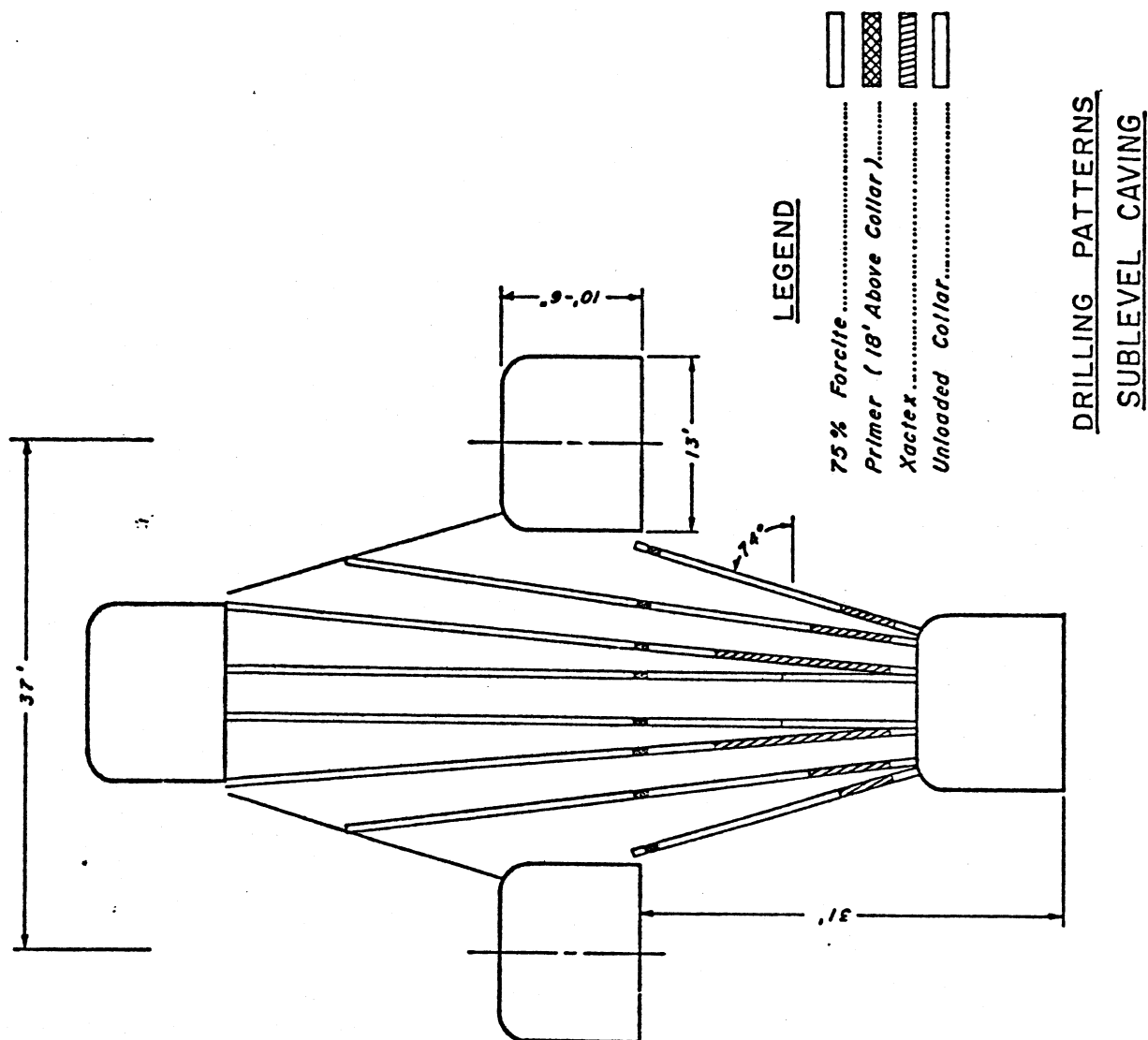
Equipment in use at present is as follows:-

- 4 ST4A Scooptrams
- 4 ST5 Scooptrams
- 1 3 boom Gardner-Denver Development Jumbo, with Deutz engine (F4L812) and DH 123 Rock Drills
- 3 2 boom Jumbos as above
- 2 Atlas Copco Simba 26 (modified) Fan Drills with two BBC 120 drills. Air motor traction.
- 2 Gardner-Denver Fan Drills modified by mounting on John Deere 440 Timber Skidders with Deutz engine (F4L912)
- 1 Gardner-Denver Fan Drill, with air motor traction and two 93 LAR rock drills.
- 1 Craigmont made Jumbo, mounting Gardner-Denver booms, etc., and two 93 LAR rock drills, with air motor traction.
- 1 Jumbo for hole cleaning, consisting of Gardner-Denver telescopic boom with one 93 LAR machine mounted on a TD 6 tractor.
- 1 Wills Wagon Drill mounting two BBC 35 rock drills for drilling holes for rebars.
- 1 Sand Truck for shotcreting. Box mounted on John Deere 440 Skidder with Deutz engine (F4L912).
- 3 Mercedes Benz type 411 Service Vehicles (two for blasting trucks, with scissor lift platforms; one mechanics vehicle).
- 6 Mercedes Benz type 406 Service Vehicles (two for shotcreting and pipe-fitting; one for development blasting and spare; two for timbering with hydraulic lift platforms; one for mechanics).
- 5 Model H True Gun-all trailers.
- 1 Galion Grader - model 503A with Deutz (F4L812).
- 2 25-ton Trolley Locomotive; one Goodman, one Clayton.
- 2 256 cu. ft. Granby Cars.
- 3 72 in. Sheldon Vane-axial Fans with 400, 450 and 500 H.P. motors.
- 1 72 in. Jeffrey aerodyne Fan with 150 H.P. motor.
- 2 42 $\frac{1}{4}$ Joy 1000 Axi Vane Fans - 60 H.P.
- 2 27 $\frac{1}{4}$ Joy 1000 Axi Vane Fans - 40 H.P.
- 6 24 KG Woods Aerofoil Fans - 32 H.P.
- 5 24 KVL Woods Aerofoil Fans - 20 H.P.
- 4 38 K Woods Aerofoil Fans - 40 H.P.
- 8 5 Ton Atlas Battery Locomotives.
- 1 8 Ton Sala Locomotive (30 AGV) with F4L 812 Deutz Engine.
- 1 5 Ton Plymouth FMD-24 Locomotive with F4L 812 Deutz Engine.
- 3 Atlas Copco Cavo 320 Mucking Machines.



SCHEMATIC SECTION

CRAIGMONT
MINES LIMITED
MERRITT, B.C.



Litteratur:

1. Information Brochure on the Operation of Craigmont Mines Ltd.-(1968).
2. The Geology of Craigmont Mines.-J.F. Bristow (1968).
3. Some Practical Problems of Sublevel Caving at Craigmont Mines.-
E.W. Cockayne (1972).
4. Craigmont Mines - Milling. - (1973).

Original reserves of approximately 75,000,000 tons of ore grading 0.52% Cu are contained in three pits. The largest of these, the Ingerbelle on the west side of the river, is presently being mined. In order to start mining operations in the Ingerbelle pit, approximately 4.2 miles of highway had to be relocated.

Two smaller pits, the Similkameen Pits 1 and 2, are located on the east side of the valley in the vicinity of old Copper Mountain mine.

Mining is generally carried out on a 3-shift five-day per week schedule at a mining rate of about 90,000 tons of ore and waste per day. Weekend mining is occasionally scheduled and weekend mine maintenance is scheduled as required.

A working-stripping ratio of 2.3 to 3:1 is maintained. Bench heights are designed at 40 feet and the overall final wall slope varies between 45° and 50°.

PIT EQUIPMENT

Shovels	Four P&H Model 1900 10 cu.yd. bucket capacity
Drills	Three Bucyrus-Erie 60R Electric 9 7/8" diameter hole using rotary tri-cone bits
Trucks	Fifteen 100-ton Lectra Haul Tires 2700 X 49 - 42 ply Engines GM12V - 149T Generator and Electric Drive by G.E.
Auxiliary	2 - Cat D-8 bulldozers 2 - Cat Model 14 road graders 3 - Cat 824B rubber-tire dozers 1 - Wabco 32-ton fuel and lube truck 1 - Wabco 32-ton water truck 1 - LeTourneau 15 cu.yd. loader

PERFORMANCE

Shovels	Scheduled 3 shovels out of 4 at 10,000 tons/shovel/shift
Trucks	Scheduled 11 trucks from fleet of 15
Drilling	22' x 22' pattern 9' sub-grade
Blasting	Powder factor .37 ANFO loaded in 96% of drill holes Wet holes are pumped, lined with 10 mil plastic sleeves, and loaded with ANFO

Similkameengruvan-kompletterande uppgifter

Våra värddar var Glen Martin, verkställande firektör - Jim Mullen, gruv-intendent och Jim McCue, förste ingenjör.

Ingerbelledagbrottet innehåller kopparkis med ca 0.005% guld. Brytningen där förväntas kunna fortsätta till 1986-88. I de två andra dagbrotten, som inte är i produktion ännu, består malmen av bornit. Brytningskostnaden är 0.30 \$/ton räknat på 7 dagarsvecka. Just nu (12.9.74) får man 0.66\$/lb för sin kopparslig men anser sig behöva ca 0.80 \$/lb för en lagom vinst. Sligen håller ca 28% koppar och säljs till Japan. Flaskhalsen i produktionen är kvarnarna där kulor sätts till trots att anrikningsverket projekterades för autogen malning.

400 man jobbar i gruvan varav 300 är arbetare och 6 st bergsingenjörer. Omsättningen bland arbetarna är ca 5% per månad i genomsnitt, högst på sommaren och nästan ingen alls under okt-mars. Friluftslivet lockar till hög frånvaro. Man har 30 kvinnliga anställda varav 14 arbetar i dagbrottet. Bortsett från problem med omklädningsrum är man nöjd.

Gruvadministrationen håller på att läggas på data. Nu databehandlas löner och personaluppgifter. Lagerhållningen av reservdelar och förbrukningsmaterial kommer härnäst. Databehandlingen görs i Connecticut på USA:s Atlantkust så omloppstiderna blir långa och Glen Martin betvivlade nyttan av det.

Man borrade med 9 7/8" tri-cone kronor och fick ut 1850-2000 bormeter av dem för en total borrhningskostnad på 2.10\$/m. Man sprängde 2 raders salvor om 39-100 hål med 15 ms fördröjning för en borrhnings- och sprängningskostnad på 0.05 \$/ton. Krutfaktorn var enligt uppgift nu 0.31 och man fick ut 75.000 ton malm och gråberg/dygn med en gråbergsinblandning på 3.4:1.

Litteratur

1. Similkameen Mining Co. Ltd.-informationsbroschyr

The Lucky Friday Mine

The Lucky Friday mine east of Mullan, Idaho is an outstanding example of a property in the famous Coeur d'Alene Mining District where a small and insignificant-appearing silver-lead-zinc vein discovered on the surface has been developed at depth into a large vein of great importance. The Lucky Friday vein has little, if any, surface expression and above the 1200 level the ore shoots are small and discontinuous. Between the 1200 level and 4250 level, the lowest developed level, the main ore shoot has shown remarkable improvement on each succeeding lower level, and today the mine is one of the major lead-silver producers in the Coeur d'Alene district.

The Lucky Friday mine employs 196 men and produces 750 tons per day of mine run ore on a five-day-a-week basis. The day shift and the night shift are the two production shifts. A small crew on the graveyard shift takes care of necessary shaft repairs and miscellaneous work. The mill operates on a 24-hour-three-shift basis, on the same five-day-per-week schedule. The breakdown of employees is shown as follows:

Underground crew.....150

Service crew (electricians
and mechanics, yard, etc).. 15

Mill crew..... 10

Engineering and geology,
office and supervision..... 21

Total.....196

The ore occurs in a tabular "vein" or fissure, varying in width from a few inches to several feet. The maximum length of ore developed on the vein is about 1,450 feet.

The ore is developed at vertical intervals (called "levels") by a system of laterals, crosscuts and drifts. The levels are connected by driving openings called "raises", at intervals along the vein.

The resulting ore "blocks" are then "stoped" (mined out) by removal of successive horizontal slices, starting at one level and working gradually up to the next level. After each slice is removed, the resulting void is sand-filled (using mill tailings). The next slice is then mined, using the sandfill as a floor.

Broken ore is hauled to the shaft, hoisted to the surface, crushed, ground, and concentrated in the mill by a flotation process.

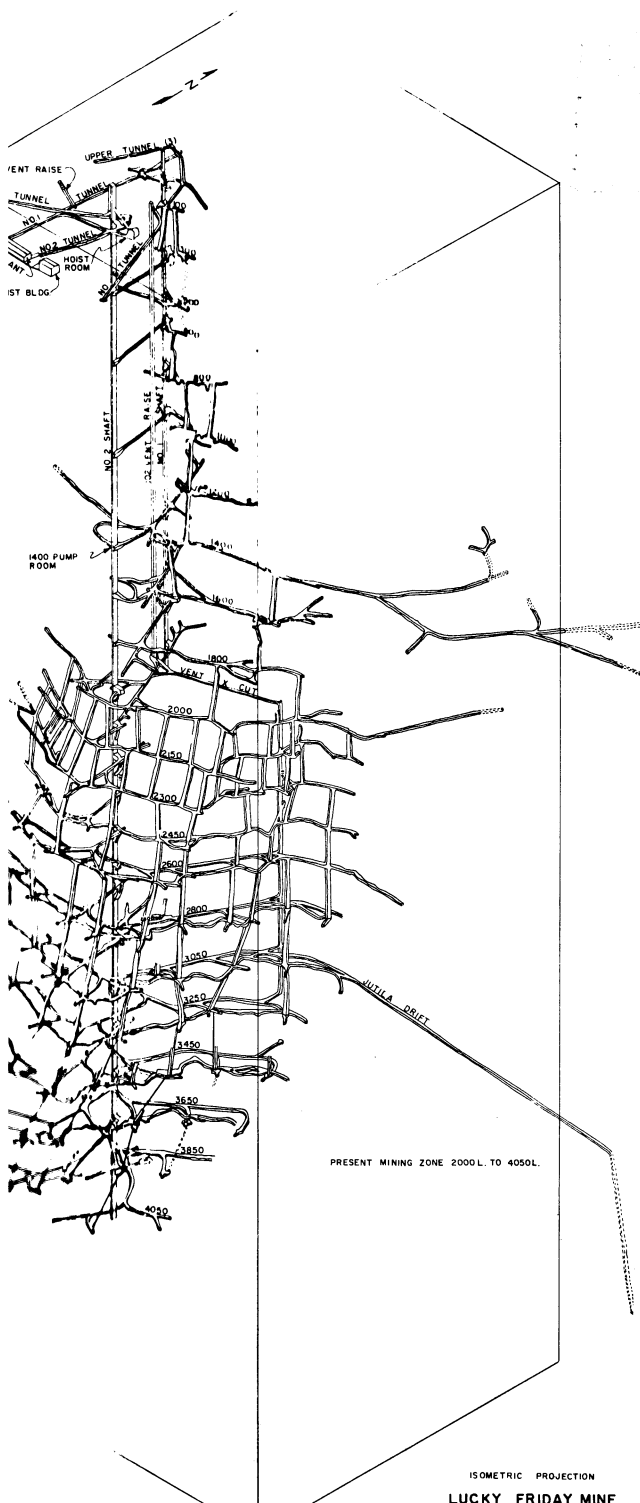
The mill produces a silver-lead concentrate and a zinc concentrate. The concentrates are shipped to the Bunker Hill Company smelter near Kellogg, Idaho. The smelter extracts the final product of the metals as silver, lead, and zinc.

The Lucky Friday mine has recently experienced two periods of major expansion. The first period (1953-1957) consisted of a new 3,161-ft. three-compartment shaft, a 400-h.p. double drum hoist capable of hoisting from a maximum depth of 3,000 feet, a new mine water pumping system capable of pumping 700 gallons of water per minute, and the development of ore reserves of about 750,000 tons. Production during this period was gradually increased to a rate of 180 tons per day.

The second period of expansion took place in 1959 following development of the 3050 level, which resulted in sufficient ore reserves to warrant construction of a new and modern mill. This program was designed to increase tonnage to about 750 tons per day at an investment of about \$1,000,000. The construction program consisted of the following: A new 750-ton per day concentration mill, an underground conveyor system to eliminate track haulage from the shaft to the mill, surface plant buildings, and an underground sandfill system.

The most recent improvement at the mine was installation of a new 1250-h.p. Nordberg double-drum hoist, designed to maintain mine production at approximately 750 tons per day at depths below the 3050 level. The hoist is capable of 5,000 feet of vertical depth. It hoists 5-1/2-ton capacity skips at a speed of 1,750 feet per minute and was installed at a cost of about \$500,000.

In 1964, Lucky Friday Silver-Lead Mines Company was merged into Hecla Mining Company.



Lucky-Fridaygruvan-kompletterande uppgifter

Värd var Jon Langstaff, förste bergmekanikern vid Hecla Mining Co. Han berättade att av eruptiva bergarter hade man bara kvartsmonzonit. I övrigt fanns sedimentära bergarter med blyglans och zinkblände som mineral. Malmen håller 10% bly, 1.5% zink och 0.043% silver. Dessutom finns gångar av kvarts och siderit. Han gav också följande uppställning av bergets egenskaper:

tryckhållfasthet	840-3500 bar	typvärde	1750 bar
draghållfasthet	140- 350 bar	"	280 bar
elasticitetsmodul	140- 910 kbar	"	455 kbar
Poisson's tal	0.05-0.24	"	0.14

Gruvan ligger nära en förkastningszon. Hela gruvdistriktet har höga horisontella bergtryck, ofta 2-3 ggr större än de vertikala. Detta medför dels att berget kryper dels att man har smällberg. Ett brytningsrum kan t.ex. slutas ca 0.5 m på 4-5 år, en mätning på 4450 fots nivån i ett oklätt schakt på 8x3 m gav en slutning på 0.25 m i längsriktningen och 0.1 m i tvärled. För att motverka detta bultar man och klär med timmer. I de djupare delarna av gruvan var både temperatur och luftfuktighet mycket höga.

Smällberg förekom 11 ggr under 1973, totalt 500 m³ berg lossnade men inga döda. Under 1974 förekom fram till 13.9 inget smällberg alls. Det är dels lokaliserat till pelare under brytningsfasen dels förekommer det under tillredningen. Man spränger regelbundet 2-4 hål om ca 6 m snett framför strossen för att flytta bort spänningskoncentrationen och därigenom undvika smällberget. Dessutom spränger man av samma anledning 6 m:s vertikala hål i rader med 1.5 m:s avstånd när brytningsfronten kommit närmare än 20 m från det ovanliggande nu sandfyllda brytningsrummet. Hålen laddas fullt med 75% dynamit till 3.6 m höjd och detoneras simultant. Man får då enligt uppgift eventuellt något kontrollerat smällberg men sedan går strossningen utan problem.

Sedan hösten 1973 har man installerat ett mikroseismiskt detekterings- och lokaliseringssystem. Det utvecklades av US Bu Min. i Denver för en annan gruva i samma distrikt och används i Lucky Fridaygruvan i modifierat skick, se särskild beskrivning. Här följer några kostnadsuppgifter om det:

geofoner från Geospace i Houston,	ca 10\$/styck
förförstärkare Ithaco 148 ML	ca 240\$/styck
jämförare Calax modell 555	ca 56\$/styck
kabel	ca 4.50\$/m
Totalkostnad för systemet	20.000\$
Dessutom tillkommer datorhyra	1.000\$/mån

Man har inte haft något smällberg sedan systemet installerades i december 1973 och kunde därför inte uttala sig om dess tillförlitlighet. Med en ansatt vågutbredningshastighet på 5560 m/s har systemet en förväntad noggrannhet på 1.5-15 m.

SEISMIC DETECTION SYSTEM
AT THE LUCKY FRIDAY MINE

INTRODUCTION

Mines in the Coeur d'Alene District of Northern Idaho are famous for their deep-seated ore bodies. Of the seven producing mines in the district, six are mining at depths in excess of 4000 feet below surface and one, the Star, is mining at 7700 feet below surface, making it the deepest lead-zinc mine in North America.

Mining at ever increasing depths creates a number of serious problems. Perhaps one of the most baffling and frustrating of these is rock bursting. All the deep mines in the district have encountered rock bursting to some degree, and no doubt the problem will tend to increase as greater depths are reached.

Past geologic history has imposed a "residual" stress in rocks of the Coeur d'Alene district. The major component of this residual or "in-situ" stress acts in a near horizontal direction often perpendicular to the veins. The combination of these residual stresses with those which are mining induced, produce forces that can even exceed the compressive strength (25,000 psi) of the very hard and brittle Revett quartzites. Rock bursting occurs when these high strength rock units fail suddenly.

Past experiences at district mines show that many different combinations of mine openings can produce bursts. Bursts have occurred in sill-pulling operations, in unmined pillars, in first-floor drifts and in virgin ground far removed from other mining activity. Bursts happen in shaft bottoms and raise headings, and are found in old abandoned workings where mining activity has ceased for years.

Hecla Mining Company's Lucky Friday Mine, like other deep mines in the Coeur d'Alene District, has experienced some rock bursts. While the problem here has not been so acute as with some of the other district mines, the problem prompted continuing investigation of rock burst ground failure. Experiments were started in techniques that might control the impact of rock bursts on the mining operation. Recent developments by the USBM in micro-seismic detection techniques indicate that a system could be designed to operate on a continuous basis in the mine environment and provide information that could be used to pinpoint the location of stress buildup and potential rock burst sites. Although the research effort in this field is by no means

completed, and many inconsistencies still exist, results obtained thus far encouraged Hecla's management to go ahead with the installation of a seismic detection system in the Lucky Friday Mine. This is a sophisticated system employing extremely sensitive seismic detection devices coupled with the latest in computer technology.

LOCATION AND GEOLOGY

The Lucky Friday Mine is located near the eastern edge of the Coeur d'Alene Mining District, about one mile east of the community of Mullan, Idaho.

The mine produces some 180,000 tons of ore per year averaging about 16 ounces Ag/ton, 11% Pb, and 1% Zn. Since 1960, it has been the third largest silver producer in the United States.

Veins in the Coeur d'Alene District are typically fissure fillings closely associated with major district faults. By far the most predominant fault in the district is the Osburn Fault, a steeply dipping, northwest trending structure with an apparent right lateral strike slip displacement of 16 miles. The Lucky Friday vein lies between two parallel subsidiary faults some 1000 feet north of this major crustal break.

The ore body itself is a steeply dipping fissure vein ranging in width from a few inches to more than 20 feet, but averaging about eight feet wide.

Ore mineralization is argentiferous galena with lesser amounts of tetrahedrite and sphalerite. The gangue consists primarily of wallrock and quartz with minor amounts of siderite. The host rock is medium to thin bedded quartzites and argillites of the pre Cambrian Belt series Revett formation.

Changes in dip and strike of the vein, as it is influenced by a steeply plunging anticlinal fold, serve to complicate the local geology. Several post mineral, offsetting faults add to this complication.

MINING METHOD

Mining is done by the cut-and-fill method using standard techniques of drilling, blasting, slushing and sandfilling. Development of the ore body is carried out by a system of laterals and crosscuts driven in the footwall of the vein from a vertical shaft. Levels are 200 feet apart and a new level is brought into production about every eighteen months. Raises are spaced about 200 feet apart along the strike of the vein and intermediate drifts are driven 25 feet above track level for the full vein length.

Subsequent mining is done by breasting-down or backstopping depending on local conditions. Generally, an eight-foot cut is taken and the mined out portion filled with a sand-cement mixture.

Haulage on the levels is by rail using battery-powered trammers and 60 cu. ft. Granby type cars. Mining is currently being done on eight separate levels, but 90% of the production comes from the lower four levels. At present, the 4050 level (elevation 700 ft. below sea level) is the bottom production level. The 4250 level (-900') is in the development stage and the main shaft has been extended to below the 4450 level.

RESEARCH BACKGROUND

Investigations conducted in the district mines in recent years have pointed out a definite relationship between the stress buildup in a rock mass caused by mining activity and the emission of audible and subaudible seismic activity (micro-seisms).

In 1968, a concentrated joint effort by USBM Denver Mining Research Center and American Smelting and Refining Company at Asarco's Galena Mine was undertaken to verify several theories regarding the generation of micro-seisms. Findings thus far indicate that:

1. Rocks under stress emit detectable seismic energy.
2. The energy source can be located using a triangulation method involving travel time differences to various receiving stations.
3. The rate of release of seismic energy increases with increasing stress and
4. This increase in noise generally precedes a major rock failure (rock burst).

In their Galena Mine research and in parallel research projects concerning "bumps" in coal mines, the USBM Denver Mining Research Center has developed instrumentation that is commercially available and has proven itself to be reliable, relatively inexpensive and sturdy enough to withstand an underground environment. Hecla engineers drew on this background to design a seismic detection network incorporating many of these instruments. It is coupled with a Hecla-designed monitoring system and a high speed, "real time" digital computer.

The Lucky Friday seismic detection system consists of 23 seismic monitoring devices (geophones) and their attendant amplifiers, stratigically placed on the lower 5 production levels of the mine and linked by wire to a central junction box and power supply.

This system provides raw data in the form of electrical signals to a bank of voltage monitors which constantly scans incoming signals. When certain preset signal conditions are met, the voltage monitors send a constant voltage signal to an IBM System/7 computer. The computer in turn, continuously scans all 23 voltage monitors and when certain program conditions are met, will calculate and print out the location of any seismic event fulfilling all the preset conditions.

SYSTEM COMPONENTS.

Geophones - The geophone is the initiative instrument of the "data-gathering" part of the system. Its function is to transform the incoming seismic vibrations to electrical signals which it then transmits to an amplifier.

A seismic detector made by Geospace of Houston, Texas, is working as a very satisfactory geophone in the mine environment. It has a natural undamped frequency of 10 Hz and an intrinsic sensitivity of .81 v/in/sec. Individual geophones are mounted in a specially made plexiglas holder which is fabricated in Hecla's machine shop. The plexiglas holder is cemented to the wall rock in its desired location with quicksetting Hydra-stone cement.

An added feature of the geophone is its ability to transmit such audible noises as drilling, slushing, fan noise and other mining related activity. Even a worker's voice is clearly defined if he speaks in the vicinity of this sensitive instrument.

Amplifiers - The electrical signal from the geophone is amplified by a specially modified Ithaco preamplifier.

This "preamp" has a power output stage to amplify the geophone signal at its source (this amplifies the geophone output signal without amplifying unwanted electrical noises.). The preamp has a normal gain of 60 db (1000 x signal) but can be reduced to 40 db by simply connecting two pins on the output connector.

Power Supply - Power to drive the preamps is derived from a modular power supply that provides a constant -28 volt D.C. current.

Wire - Two different types of signal transmission line are used in the system.

A three-conductor, shielded cable is strung from each geophone to a central location where a junction box and power supply unit are located. This cable transmits power to the amplifier and the amplified signal back to the junction box.

The amplified signal is then transmitted to surface via a 27-pair, individually shielded cable.

Voltage Monitors - At the surface the amplified signal from each geophone is fed into individual voltage monitors. These voltage monitors serve as an interface between the data-gathering part of the system and the data computation and resolution part of the system.

Each monitor is individually adjustable through a range of ± 24 volts and can easily be set at any desired level within that range.

If the signal coming into the monitor exceeds a preset level, than an appropriate signal is fed into the computer and the data computation and resolution portion of the system come into action.

Computer - An IBM System/7 computer is leased to provide the data computation and resolution portion of the system. It functions to continuously scan the voltage monitors and, when certain signal conditions are met, calculates the x, y, z coordinates of a seismic event. A teletype prints the calculated results plus the time of day the event occurred.

SYSTEM OPERATION

The network of twenty-three geophones is designed to give optimum resolution of seismic events occurring within the most active portion of the mine. Geophones are located on each level from 3250 to 4050. There are three phones on 3250, four on 3450, six on 3650, six on 3850 and four on 4050. Spacing of the phones varies according to local conditions and access. The minimum distance between adjacent phones is 150 feet and the longest distance measured from one end of the system to the opposing end is 1100 feet.

When a seismic wave is picked up by a geophone, the geophone signal is amplified and transmitted to the voltage monitor. If it exceeds a preset "threshold", a 15-volt current is transmitted by the voltage monitor to the computer where it is registered as a "hit" (see attached illustrations).

In order to select a "threshold" that would not continuously activate the computer time window, it was necessary to establish some background noise values for various mining activities. It was found that drilling activity rarely exceeds a 2-volt level, and as this is the most common noise occurring in the mine, the threshold level was set at 2 volts. The voltage monitors are individually adjustable so the threshold can be varied for any geophone as the need arises.

The computer location program utilizes the standard distance equation

$$d_i = \sqrt{(x-A_i)^2 + (y-B_i)^2 + (z-C_i)^2} \quad \text{[where } d_i = \text{distance from source to geophone } i.$$

$A_i, B_i, C_i = i$, geophone coordinates
 x, y, z = source coordinates]

and the relationship $d_i = Vt_i$, [where V = average determined velocity, t_i = geophone arrival time in microseconds] to mathematically solve simultaneous equations involving the travel times and distances. The IBM System/7 computer is able to calculate up to 10 events per second.

Geophone locations are transit surveyed to accurately determine their coordinates.

The average velocity of sound waves in rock is determined experimentally by detonating small quantities of dynamite in known locations and observing

the travel times to various geophones. Experimental results indicate that velocity is dependent on many variables such as rock type, rock attitude and local stress concentrations so that the velocity may vary as much as 20%. Artificially produced (by dynamite) rock noises have been located to within 20 feet of actual location, using the above described method. Tests have shown that three sticks of 1-1/8" x 16", 60% dynamite detonated in a hole near the center of the system will trip all twenty three phones.

The computer printout of seismic event locations is inspected daily and pertinent information is recorded.

The printout for any given event includes its x, y and z coordinates, the time the event took place, the individual geophones hit and the time (in computer time) that each was hit. On an average day, forty to sixty events will be printed out (this includes blasting). The non-blasting events are logged and plotted on 50-scale plan maps of the mine. Events per day are noted on charts for each stoping area and if a buildup of seismic events is indicated a section of the area is also made.

No significant rock bursts have occurred in the mine since the system became operational in December of 1973 so the "prediction" capabilities of the system remain untested. Concentrations of seismic events have been noted in several areas, and in almost all cases these concentrations are directly related to mining operations.

At the present time the seismic detection system is mainly a "data gathering" tool. As more information is added and a statistical background is established the system will be used in the day to day operation and planning of the mine.

Jon T. Langstaff

ILLUSTRATION OF SEISMIC NOISE DETECTION SYSTEM LUCKY FRIDAY MINE

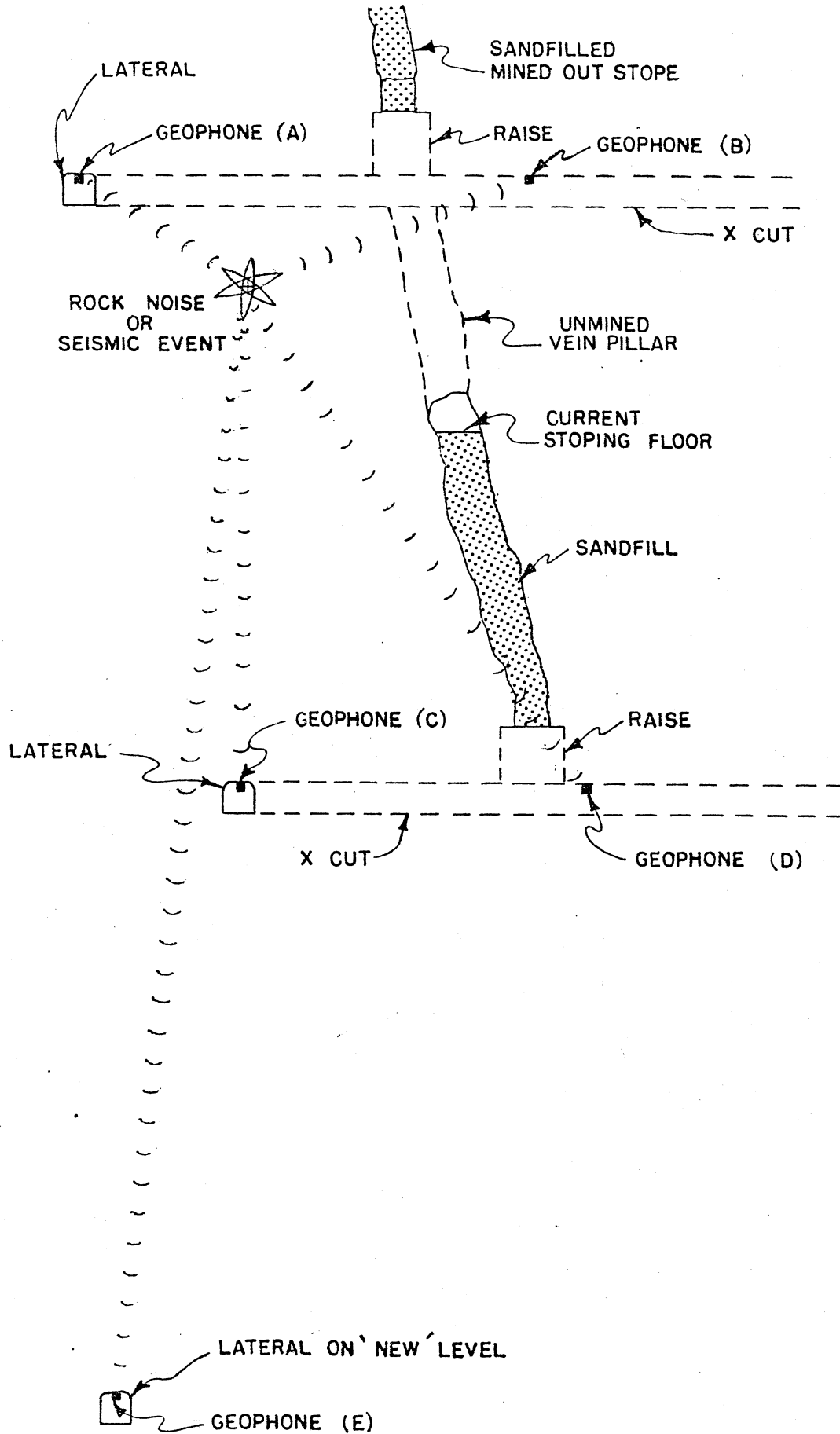
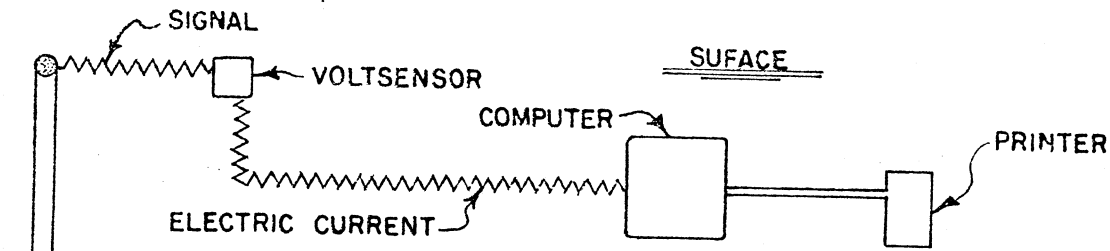


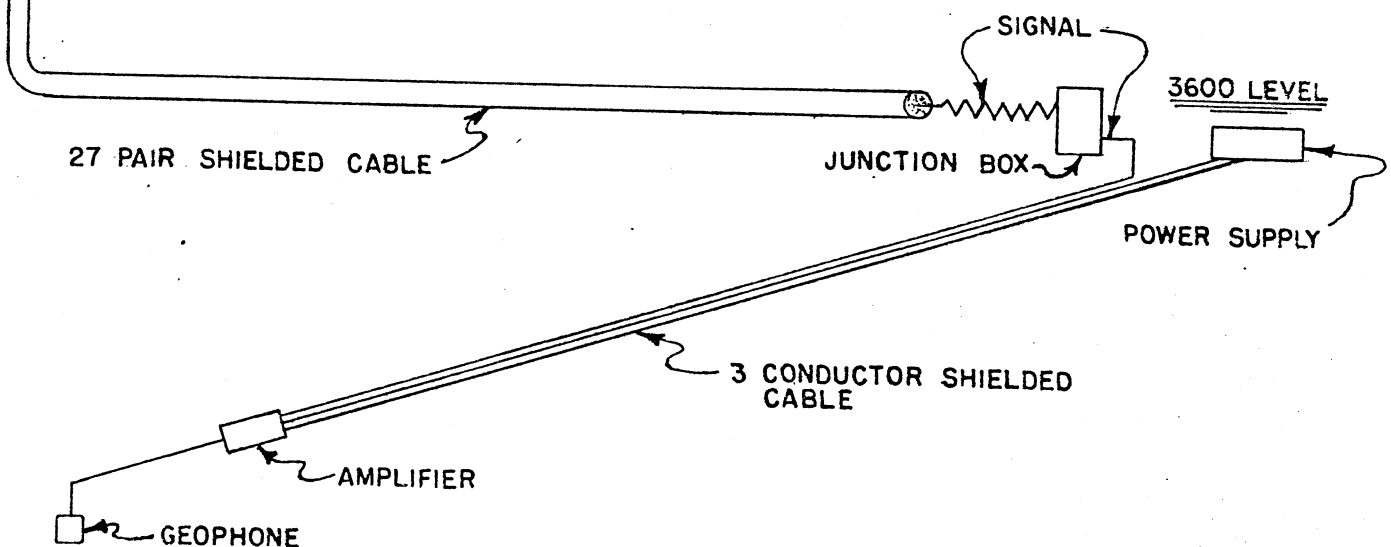
ILLUSTRATION OF SEISMIC NOISE DETECTION SYSTEM I10.

LUCKY FRIDAY MINE



NOISE MONITOR SYSTEM SEQUENCE OF EVENTS

- 1 - Seismic event occurs, sending seismic waves (noise) in all direction.
- 2 - Geophone (A) picks up noise.
- 3 - Noise is amplified x 1000 and transmitted to VOLTSensors
- 4 - Noise exceeds VOLTSensor threshold, VOLTSensor sends electric current to computer.
- 5 - Computer sets "O" time, opens time "window"
- 6 - Geophones (B), (C), (D), and (E) pick up noise, amplify etc.
- 7 - Computer receives 4 "hits" within time window, satisfying program conditions
- 8 - Computer prints out coordinates of event.



Appendix J: Spokane Mining Research Center - US Bu Min.

Värdar för besöket var George Wallace, forskningsdirektör - Robert Simpson, gruvingenjör och James McVey, instrumenttekniker. Laboratorierna hade alldeles nyligen flyttat in i sina lokaler på East 315 Montgomery St i Spokane. Kontorsdelen var färdig men många maskiner stog fortfarande i flyttemballage. Budgeterad verksamhet för 1974 var egna projekt 2.5 milj \$ och förmedlade projekt 15.0 milj \$ på sammanlagt 105 anställda.

Besöket omfattade en kort introduktion av George Wallace, ett långt besök i ett elektronik och instrumentlaboratorium som förestogs av James McVey samt en rundvandring. Här är några uppgifter om detta:

instrumentlab - deformationsgivare och datainsamling
 elektroosmoslab-fyllkompaktering
 jordlab-skjuvprov och miljöstudier
 datacentral - CDC 3200 med 32k 24 bits ord och 1.25 μ s minnes-
 cykeltid.
 Robert Simpson - pumpbara plast-glasfiberbergbultar.

Litteratur

1. Research Program fiscal year 1975 - Spokane Mining Research Center
2. J.R. McVey m.fl., A Radio Frequency Warning Device for Early Roof Failure Detection, ASTM STP 554 sid 135-146 (1974)
3. J.R. McVey m.fl., Deformation Monitoring of Underground Openings by Photographic Techniques, US Bu Min RI 7912 (1974)

SPOKANE MINING RESEARCH CENTER

George B. Wallace, Research Director

OUR MISSION

The Spokane Mining Research Center furthers the science and technology of artificial stabilization of underground openings and the use and disposal of mineral waste, both surface and underground.

OUR OPERATION

Our research is divided into 4 broad areas, each with division status, and headed by a supervising mining engineer. A supervising general engineer heads the Center's services.

These divisions pursue the following objectives:

(1) Behavior of Supported Underground Openings (Rock Mechanics)--
Develop techniques for determining artificial support requirements by evaluating the ground immediate to the opening (initial and time dependent deformation rate, rock and support properties, etc.) and determine support effectiveness in field projects.

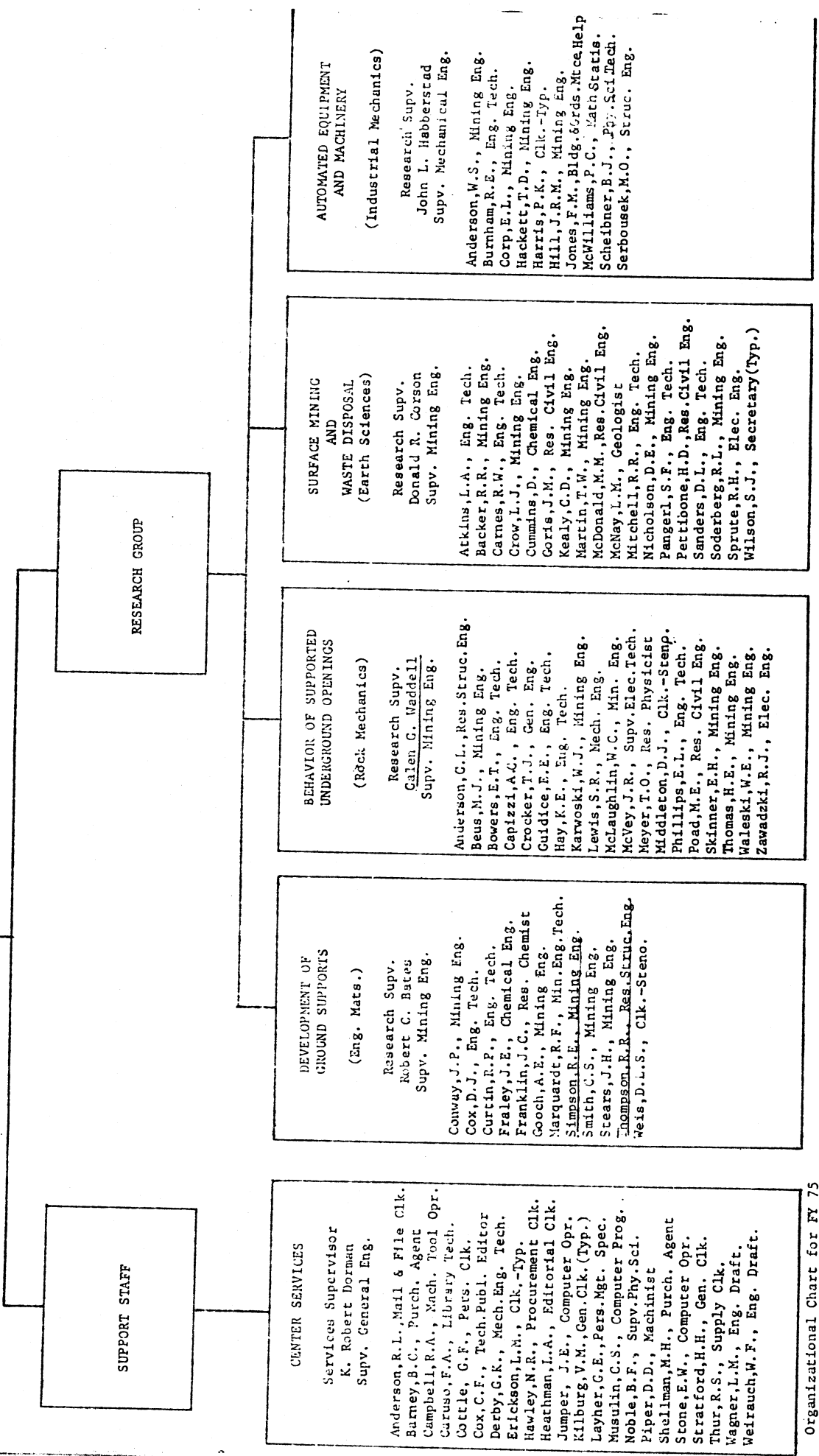
(2) Development of Ground Supports (Engineering Materials)--
Using theoretical analyses, lab experiments, and field studies, improve existing, and develop new, mine-support systems that are safer and less costly.

(3) Surface Mining and Waste Disposal (Earth Sciences)--
Develop design principles for disposal of mineral waste (tailings) or using it for underground support and for improving materials-handling systems in underground metal mines.

(4) Automated Equipment and Machinery (Industrial Mechanics)--
Develop new, or improve existing underground mine equipment to increase production and enhance safety.

(5) Center Services (Administrative Support) is responsible for clerical assistance, purchasing, personnel, safety, library, and graphics. In addition it is responsible for operation of a shop, the test adit, and our CDC-3200 computer center.

SPOKANE MINING RESEARCH CENTER
RESEARCH DIRECTOR
George B. Wallace, Ph.D. Sci. Adm.
Gloria A. Hudon, Secretary-Steno



CENTER SERVICES
Services Supervisor
K. Robert Dorman
Supv. General Eng.
Anderson, R.L., Mail & File Clk.
Burney, B.C., Purch. Agent
Campbell, R.A., Mach. Tool Opr.
Curuso, F.A., Library Tech.
Cottle, G.F., Pers. Clk.
Cox, C.F., Tech. Publ. Editor
Derby, G.K., Mech. Eng. Tech.
Erickson, L.M., Clk.-Typ.
Hawley, N.R., Procurement Clk.
Heathman, L.A., Editorial Clk.
Jumper, J.E., Computer Opr.
Kilburg, V.M., Gen. Clk. (Typ.)
Layher, G.E., Pers. Mgt. Spec.
Musulin, C.S., Computer Prog.
Noble, B.F., Supv. Phy. Sci.
Piper, D.D., Machinist
Shellman, M.H., Purch. Agent
Stone, E.W., Computer Opr.
Stratford, H.H., Gen. Clk.
Thur, R.S., Supply Clk.
Wagner, L.M., Eng. Draft.
Weirauch, W.F., Eng. Draft.

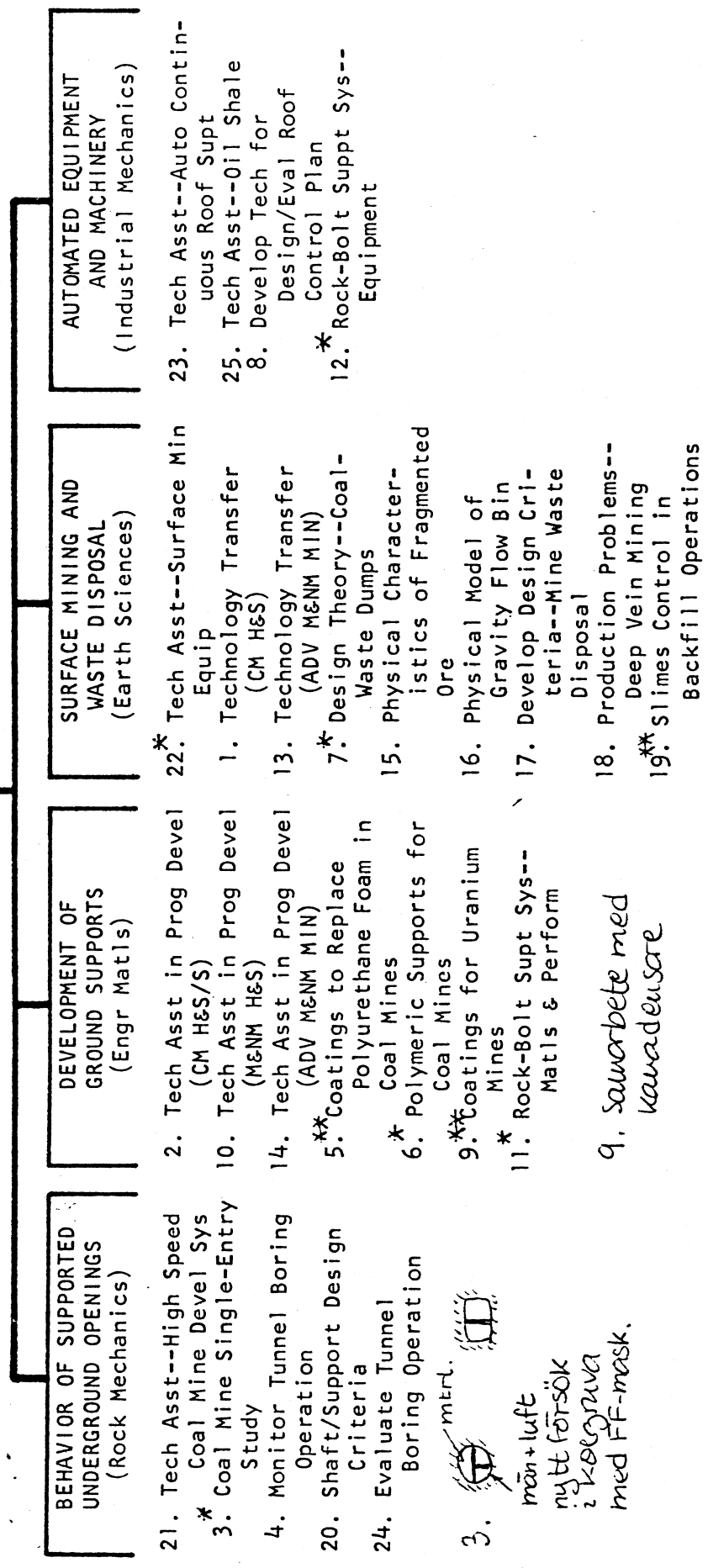
DEVELOPMENT OF GROUND SUPPORTS
(Eng. Mats.)
Research Supv.
Robert C. Bates
Supv. Mining Eng.
Conway, J.P., Mining Eng.
Cox, D.J., Eng. Tech.
Curtin, R.P., Eng. Tech.
Fraley, J.E., Chemical Eng.
Franklin, J.C., Res. Chemist
Gooch, A.E., Mining Eng.
Marquardt, R.F., Min. Eng. Tech.
Simpson, R.E., Mining Eng.
Smith, C.S., Mining Eng.
Stears, J.H., Mining Eng.
Thompson, R.R., Res. Struct. Eng.
Weis, D.L.S., Clk.-Steno.

BEHAVIOR OF SUPPORTED UNDERGROUND OPENINGS
(Rock Mechanics)
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Supv. Mining Eng.
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Beus, M.J., Mining Eng.
Bowers, E.T., Eng. Tech.
Capizzi, A.C., Eng. Tech.
Crocker, T.J., Gen. Eng.
Guidice, E.E., Eng. Tech.
Hay, K.E., Eng. Tech.
Karwoski, W.J., Mining Eng.
Lewis, S.R., Mech. Eng.
McLaughlin, W.C., Min. Eng.
McVey, J.R., Supv. Elec. Tech.
Meyer, T.O., Res. Physicist
Middleton, D.J., Clk.-Steno.
Phillips, E.L., Eng. Tech.
Poad, M.E., Res. Civil Eng.
Skinner, E.H., Mining Eng.
Thomas, H.E., Mining Eng.
Waleski, W.E., Mining Eng.
Zawadzki, R.J., Elec. Eng.

SURFACE MINING AND WASTE DISPOSAL
(Earth Sciences)
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Supv. Mining Eng.
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Backer, R.R., Mining Eng.
Carnes, R.W., Eng. Tech.
Crow, L.J., Mining Eng.
Cummins, D., Chemical Eng.
Coris, J.M., Res. Civil Eng.
Kealy, C.D., Mining Eng.
Martin, T.W., Mining Eng.
McDonald, M.M., Res. Civil Eng.
McNay, L.M., Geologist
Mitchell, R.R., Eng. Tech.
Nicholson, D.E., Mining Eng.
Pangerl, S.E., Eng. Tech.
Pettibone, H.D., Res. Civil Eng.
Sanders, D.L., Eng. Tech.
Soderberg, R.L., Mining Eng.
Sprute, R.H., Elec. Eng.
Wilson, S.J., Secretary (Typ.)

AUTOMATED EQUIPMENT AND MACHINERY
(Industrial Mechanics)
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Supv. Mechanical Eng.
Anderson, W.S., Mining Eng.
Burnham, R.E., Eng. Tech.
Corp, E.L., Mining Eng.
Hackett, T.D., Mining Eng.
Harris, P.K., Clk.-Typ.
Hill, J.R.M., Mining Eng.
Jones, F.M., Bldg. Sdr. Mccl Help
McWilliams, P.C., Math Statist.
Scheibner, B.J., Phy. Sci. Tech.
Serbousek, M.O., Struc. Eng.

SPOKANE MINING RESEARCH CENTER
RESEARCH DIRECTOR



SMRC PROJECTS BY DIVISION

(Numbers correspond to listing in FY75 PROGRAM, following)

Appendix K - Henderson och Climaxgruvorna

Vår värd i Denver, Charles Jude vid AMAX, kör finita elementprogram för släntstabilitetsberäkningar för dagbrottet i Climax på bolaget centraldator, en IBM 370 med 384 K kärnminne och virtuellt minne. Han gör också beräkningar på stålrörsinklädda tunnlar med liten täckning vid släntens fot.

Vid besöket på Hendersongruvan togs vi omhand av gruvintendenten Robert Jones. Gruvan befann sig på tillredningsstadiet och planerad startpunkt för produktionen är juli 1976. Tills dess beräknar man ha investerat ca 370 milj. \$ i gruvan. Uppskattade malmreserver är 300 milj.ton med molybdendisulfidhalt på 0.49%. Malmkroppens utbredning är ca 700x500 m. Planerad produktion är ca 30.000 ton/dag med 1100 man. Gruvlaven ligger ca 3300 möh och de första produktionsnivåerna på 2400 och 2500 möh. Brytningsmetoden är blockkrasbrytning. Malmuttransporten sker på 2300 m nivå med elektriskt drivna tåg i en 16 km lång tunnel under Klippiga Bergens vattendelare till kross- och anrikningsanläggningen.

Den utrustning man använder under tillredningsarbetet är Ingersoll-Rands och Gardner-Denvers borraraggregat med BD:s drifterborrmaskiner. Man använde dessutom Atlas Copco maskiner för långhålsborrning vid stigortsdrivning. AC:s borraraggregat var enligt uppgift för dyra. Man använde Sandvik borrstål 1 3/4 tum upp till 10-11 fots längd vid ortdrivningen. För utlastningen till produktionsschakten fanns Eimco 915 LHD lastmaskiner med 4 m³ skopa. Som kommentar till vår rundvandring: reparations- och bränsledepåer samt elcentralen var påfallande rymliga, ljusa, rena och snygga; man använde genomgående våt sprutbetong p.g.a. dammproblem. Man har Nordbergs hissar och malmskip samt använde ASEA lok för uttransporten. Man hade emellertid problem med ASEA loken och var missnöjda med dem.

Bob Jones sade att man nu under tillredningsarbetet skjuter ca 60 salvor/vecka och att man hade problem med fuktkortslutningar i tändkretsen. Bl.a. därför var han mycket intresserad av att få ytterligare upplysningar om den Nonelstubin som Ensign-Bickford gett honom ett litet prov av. Han sade att han gärna skulle vilja använda Nonel under tillredningsarbetet som i huvudsak avslutas under 1975.

De orter man driver är 14 fot breda och 13.5 fot höga med cirkulär takprofil. Man skjuter brännkilssalvor med 3 tums tomhål och åtföljande spiral med 1 3/4 tums hål på 3, 5, 7 och 9 tums avstånd. Man använder huvudsakligen ANFO, både prillat och inte prillat. Konturen slätsprängs med 7/8x24 tums Hercutrim och Trimtex stavar (motsvarar gurit).

ExV = 18x18 tum och ca 22 hål. I bottenhålen har man dynamit i bottenladdningen, hålantallet är 7. Tändföljden är 0, 1/4, 1/2, 3/4, 2x1, 2x2, 2x3, 2x4, 5x5, 6x6, 7x7, 22x8 och 7x9. Hela salvan har total 61 hål.

Climaxgruvan finns beskriven i Nils Lundborgs reserapport /6/. Värd för vårt besök var geologen John McDonough. Jag vill bara nämna något om deras berglab där man bl.a. gör kornstorleksanalys och triaxiella tryckprov med lateraltryck på 35, 70, 210, 350 och 500 bar. Normala materialdata på starkt berg är

elasticitetsmodulen ca 700 kbar

Poissons tal 0.18,

mätt med trådtöjningsgivare på cylindriska kärnor.