

HOMESTAKE MINE/DUSEL ROCK MECHANICS

Prepared for a FNL/BNL Workshop

September 16 - 17, 2006

Batavia, Illinois

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University of Utah

DISCUSSION OBJECTIVE:

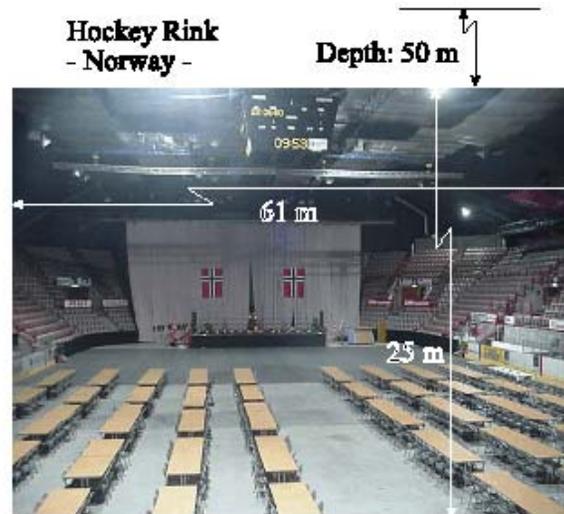
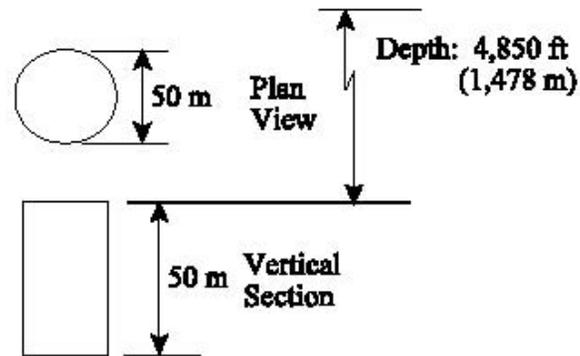
To show why I think the Megaton detector is do-able at the Homestake Site.

APPROACH

Present empirical and scientific evidence for project feasibility.

Empirical = 100 yrs operating experience.
Scientific = 20 yrs rock mechanics research.

100-kiloton detector cavern

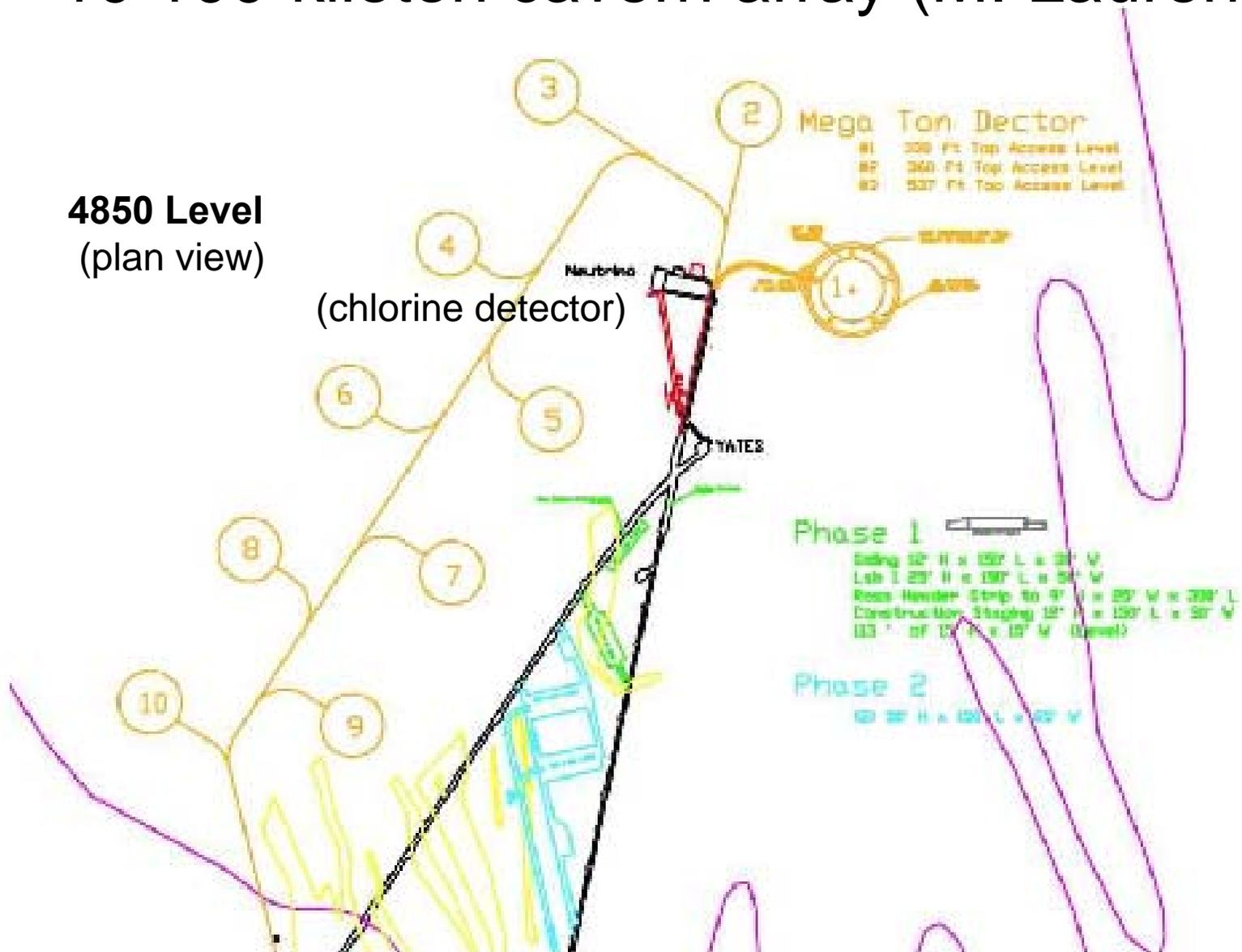


- DESIGN BASIS: (1) EXPERIENCE - underground swimming pool nearby.
(2) ENGINEERING - with monitoring during construction.

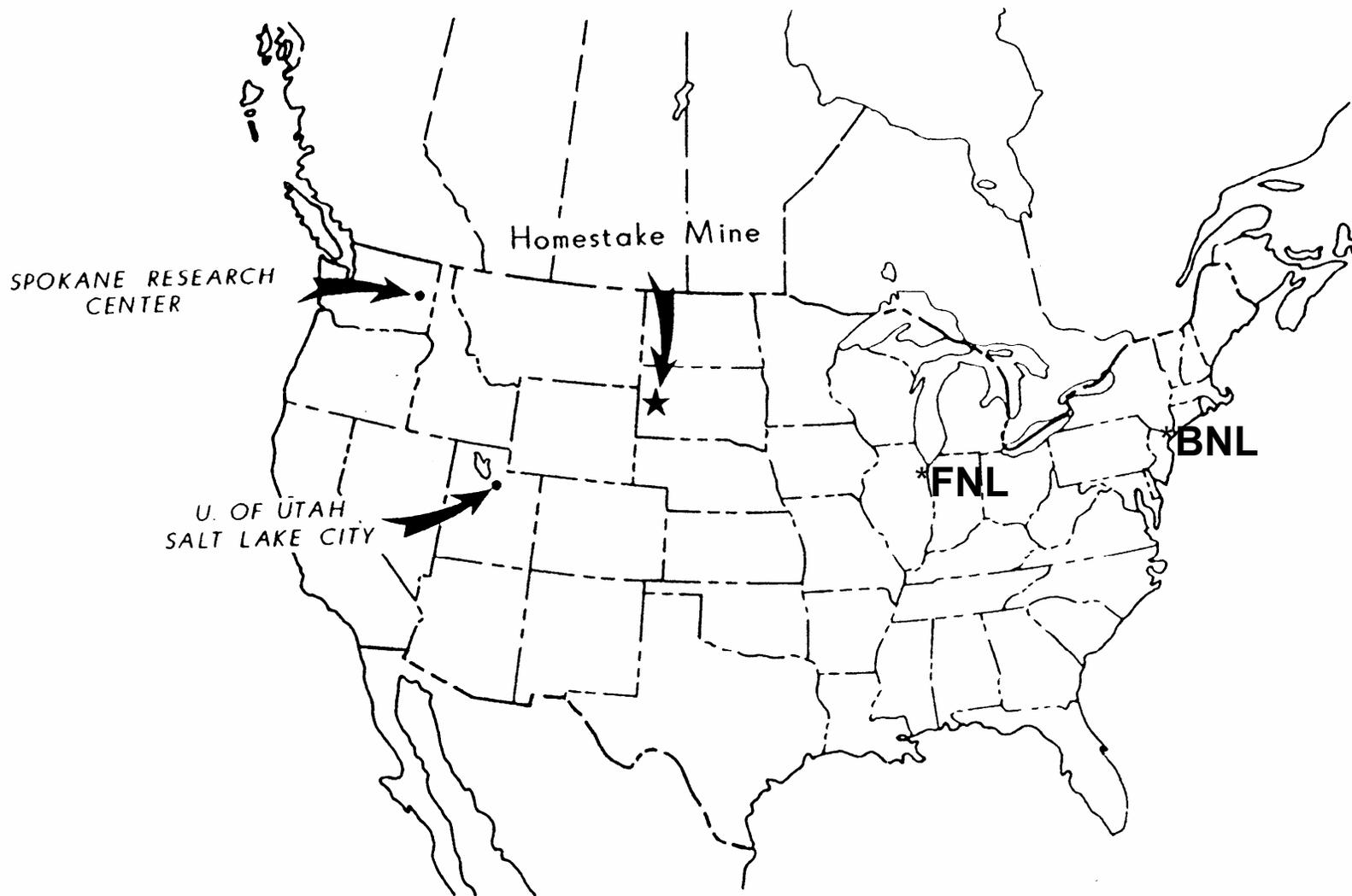
10 100-kiloton cavern array (M. Laurenti)

4850 Level
(plan view)

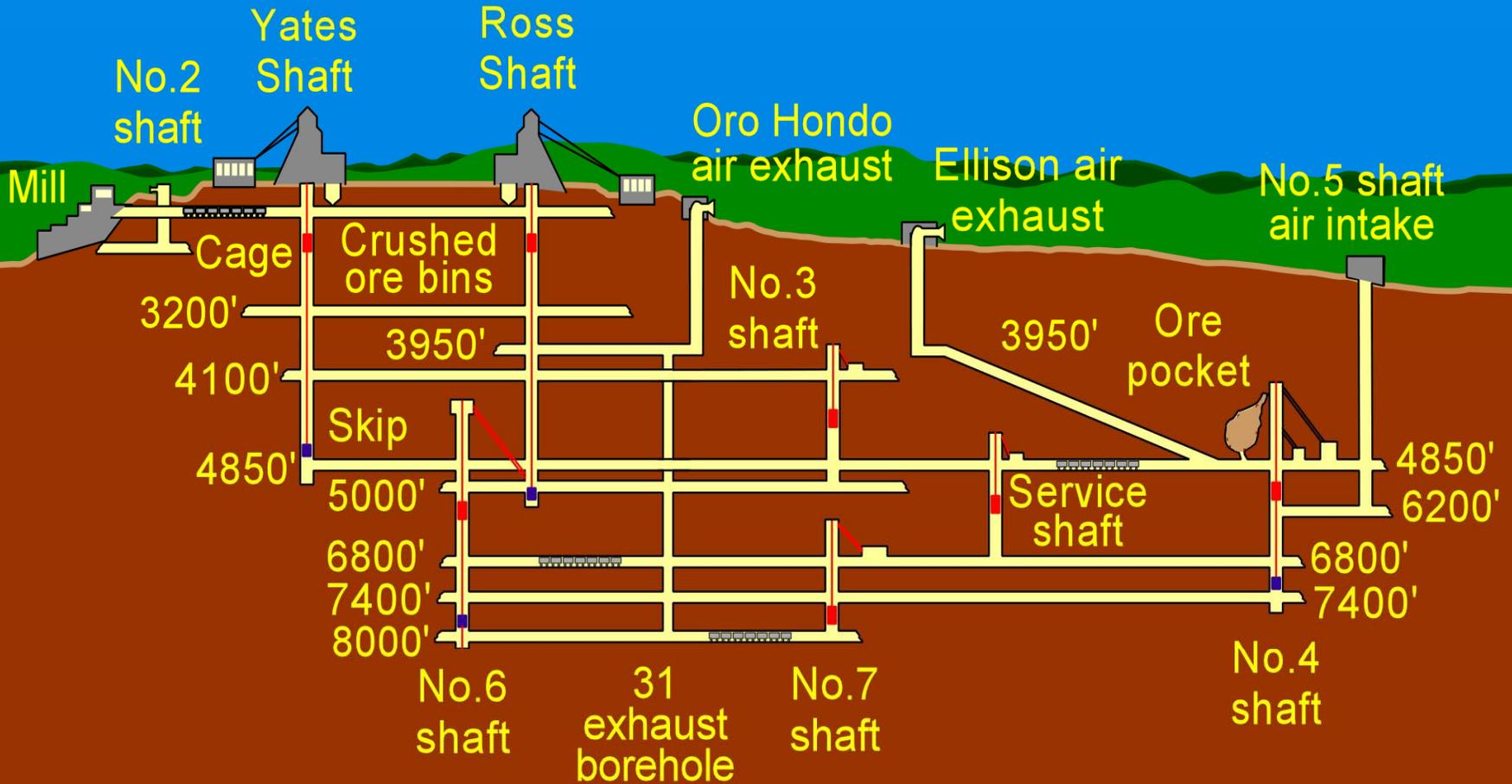
(chlorine detector)



LOCATIONS

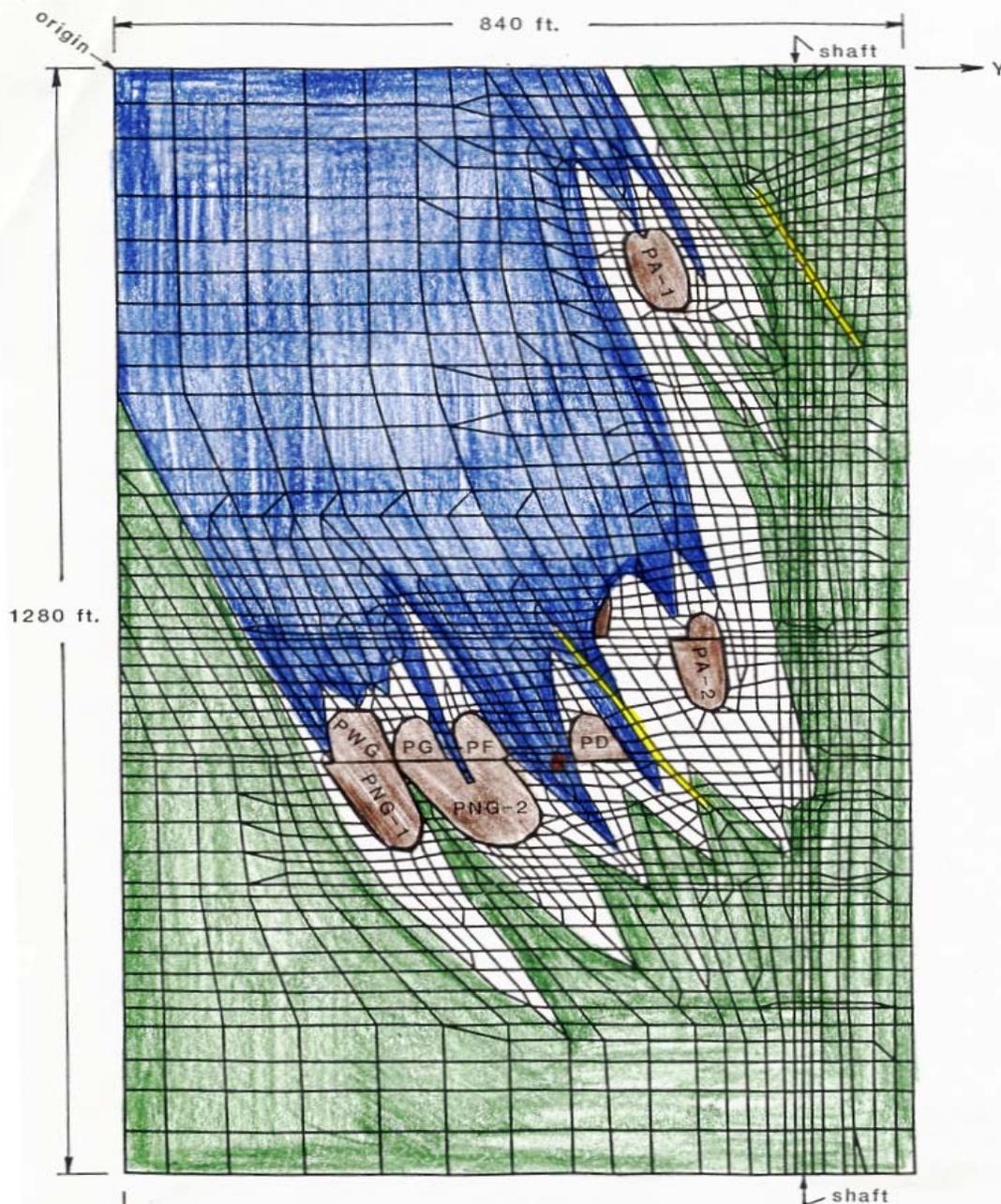


General Homestake Mine Development



ROSS SHAFT – HOMESTAKE MINE





HOMESTAKE, VERT THRU ROSS, 1"=154' 11-JUN-87

elements : 2589

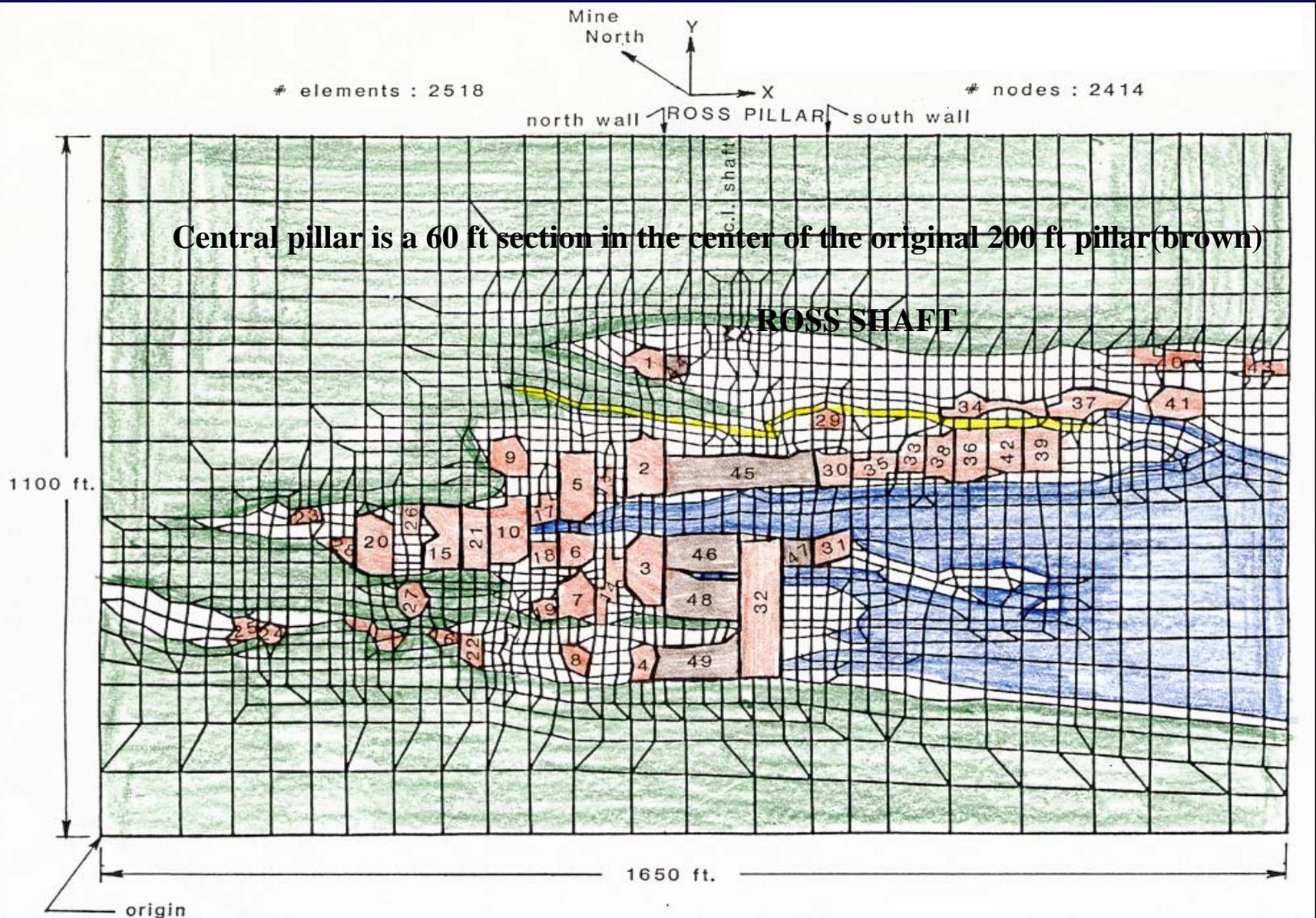
nodes : 2521

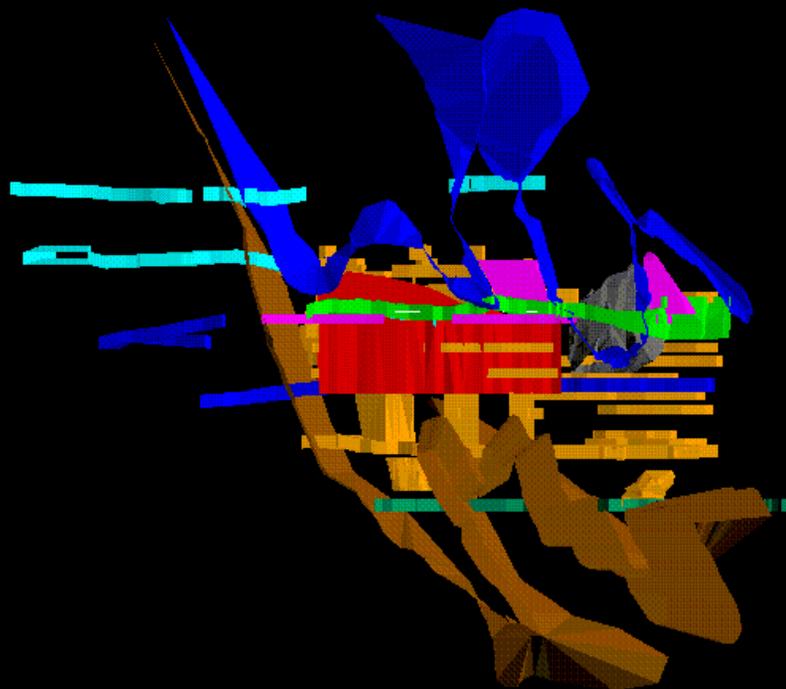
ef hmf pmt

VERTICAL SECTION:

Geology & Pillar Reserve

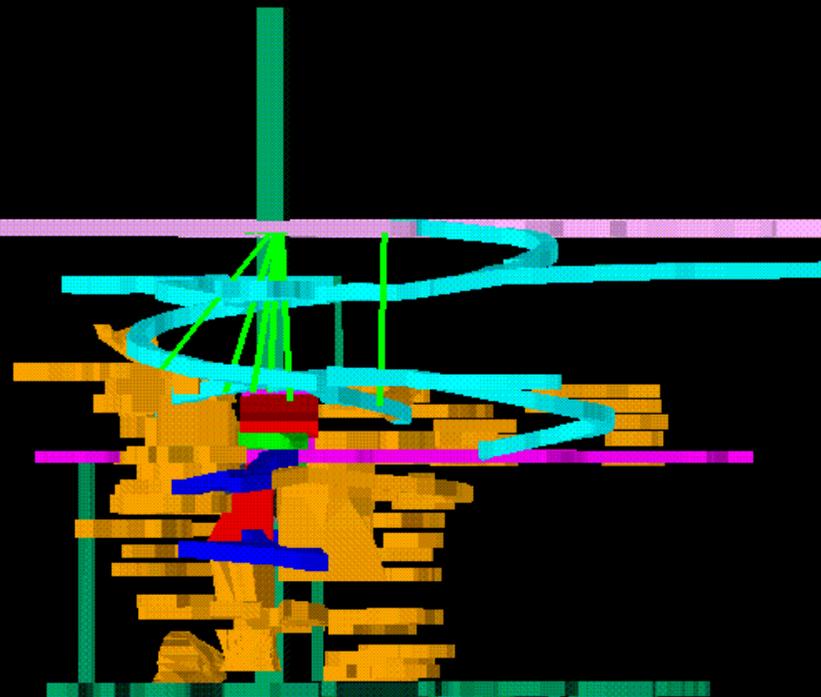
PLAN VIEW: Geology, Historic Mining, Pillar Reserve





Ross Shaft pillar
view using mine
planning software
(Homestake fold
limbs in brown.)

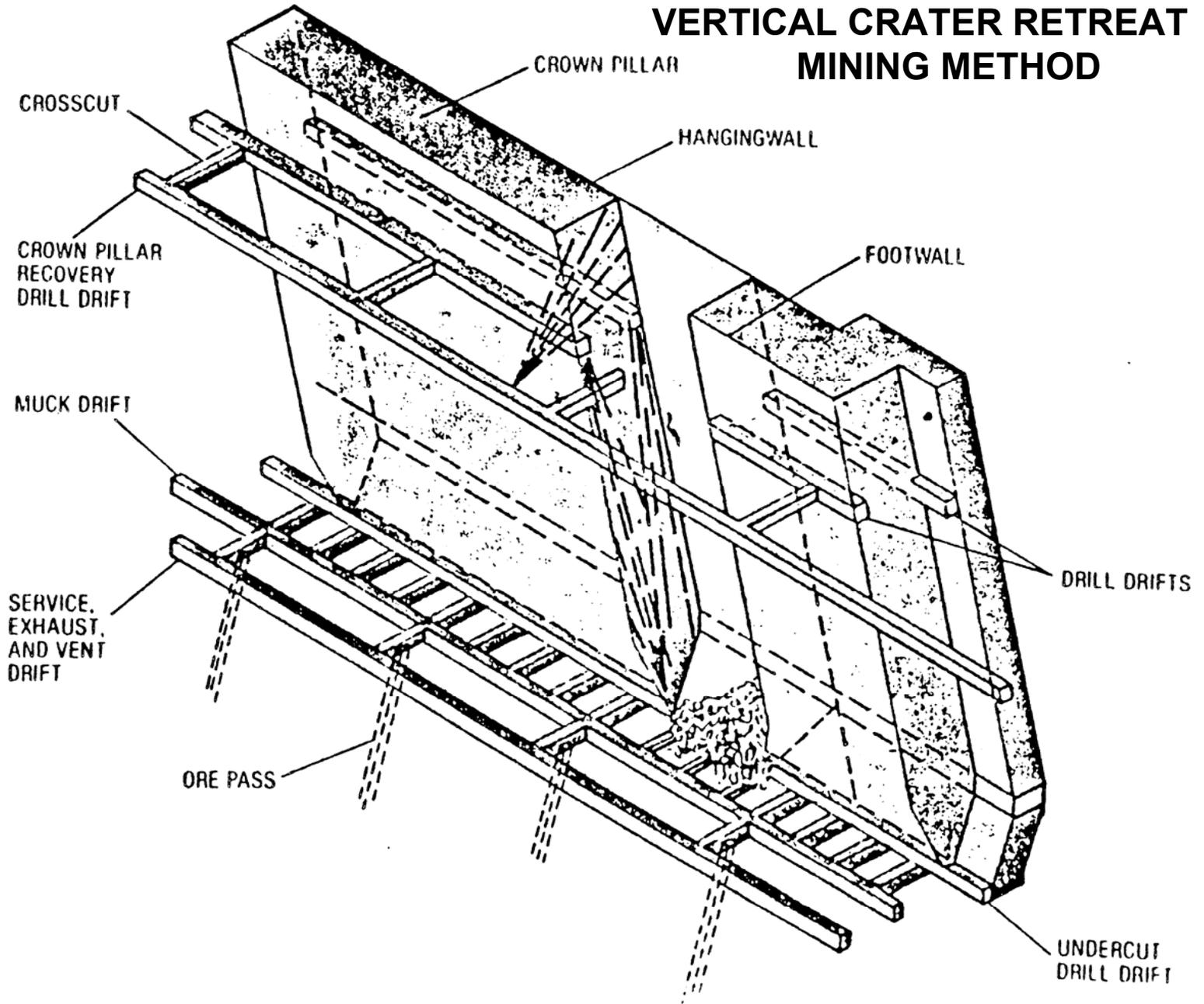
Four point MPBX's
near Ross Shaft pillar
(Hole collars on 3350 L)

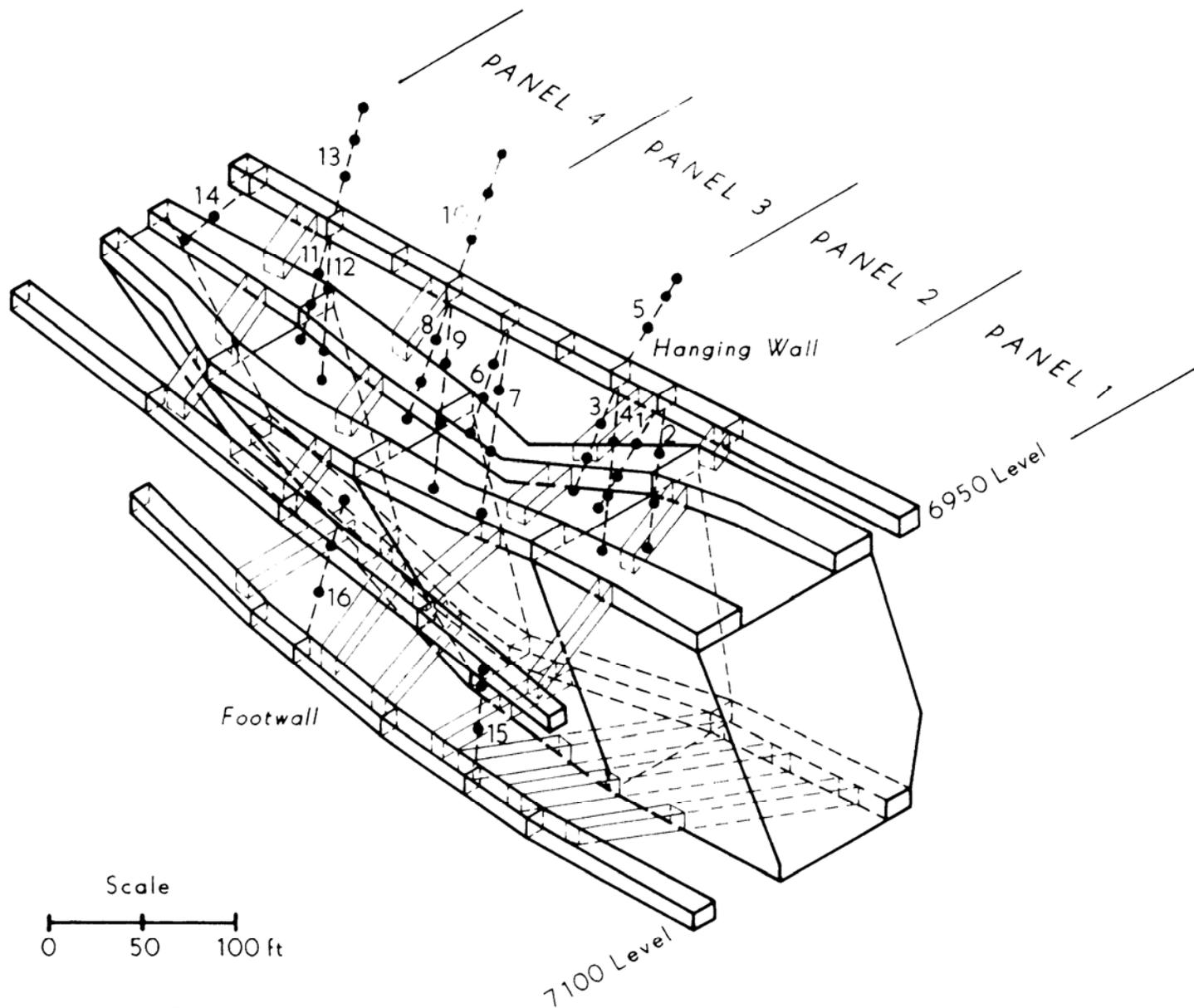


Projects at the Homestake Mine

- 1983-85 *Vertical Crater Retreat (VCR) Pillars* [US Bureau of Mines Research Contract with the University of Utah & Homestake Mine]
- 1987-90 *Cable Bolts* (bird cage, conventional) [Cooperative UU/ USBM/ HME & GMTC]
- 1987-2003+ *Ross Shaft Pillar* study [Cooperative UU/ USBM/ HME]

VERTICAL CRATER RETREAT MINING METHOD





Cable bolt drift –
cleaning borehole
extensometer holes.



Top sill and hole collars
with stemming bags in
preparation for blasting.



INSTALLATION OF BOREHOLE EXTENSOMETERS





MPBX's after installation

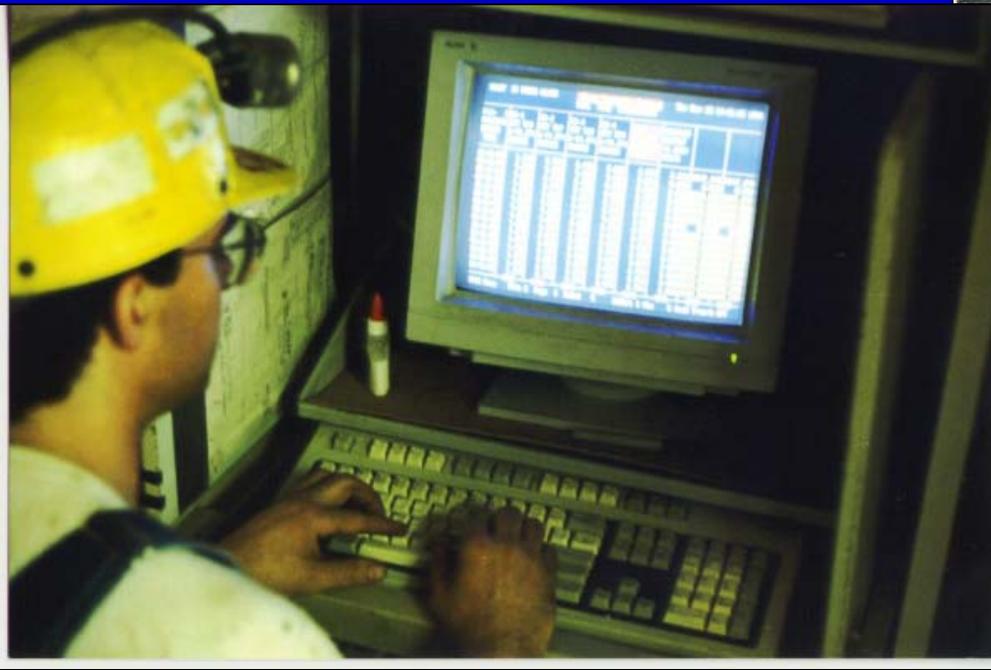
Mechanical reading check
on electrical reading



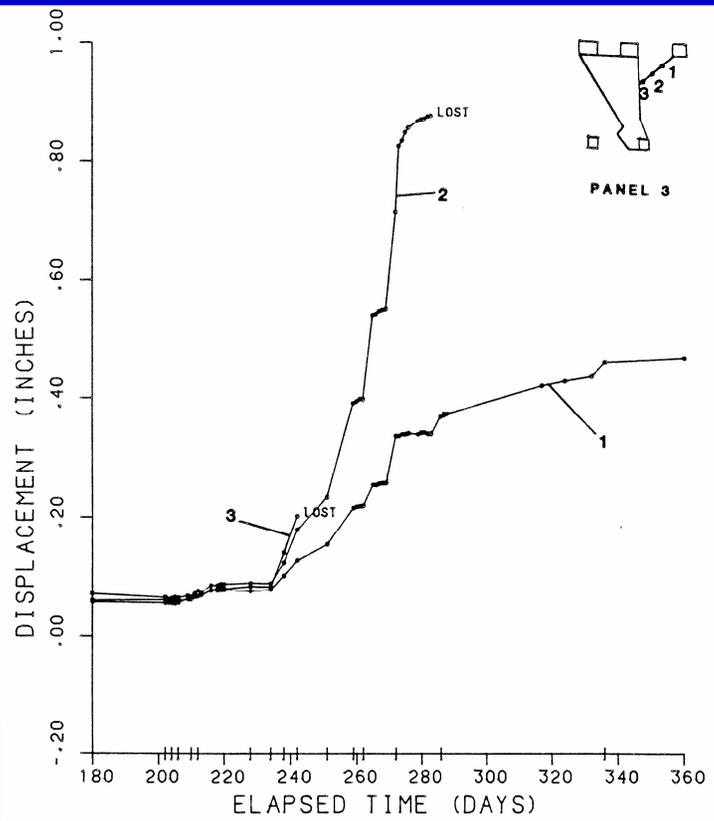


Data acquisition system

Shaft station relay



Surface station control



DAY	EVENT
0	NOV. 15, 1983
107	BEGIN RING DRILLING
122	FINISH RING DRILLING

DAY	EVENT
202	BEGIN PROD. BLASTING
283	CROWN PILLAR EAST
332	CROWN PILLAR WEST

HOMESTAKE PROJECT EXTENSOMETER DATA

HOLE NUMBER: 8

DATE: MAY 10, 1985

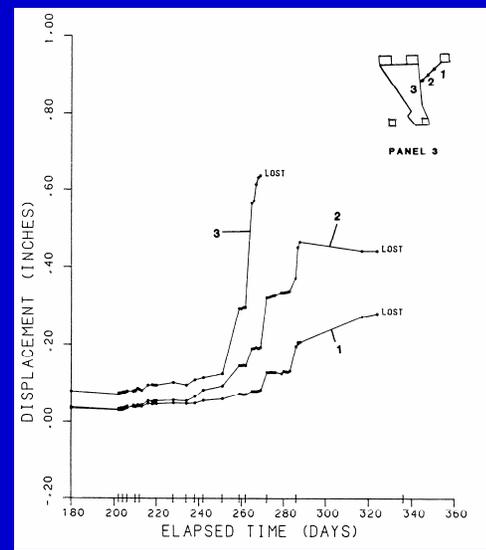
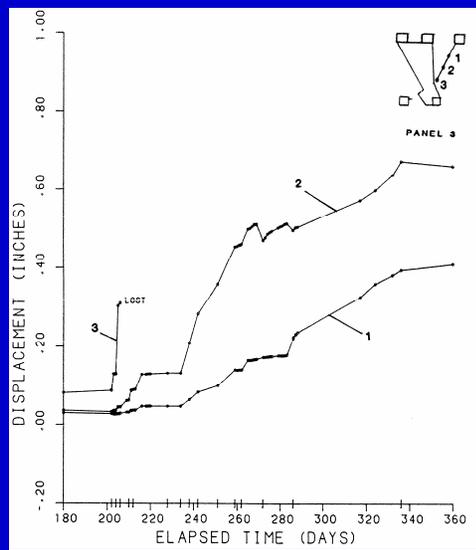
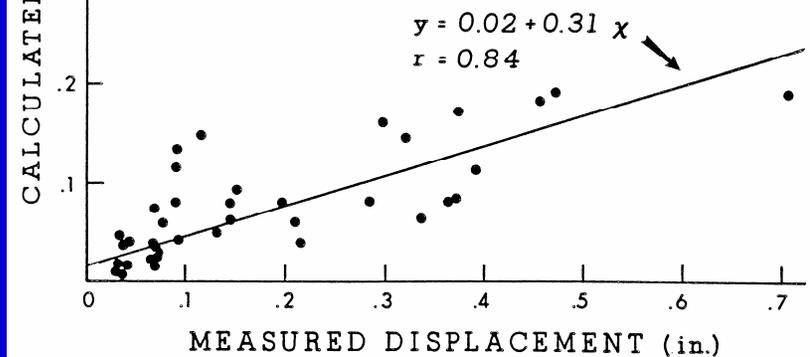


TABLE 22. - Anchor regression in the elastic range

Hole	Anchor	Slope	Correlation	Comment
6	1	0.409	0.996	after 6 cuts
6	2	0.440	0.990	after 6 cuts
6	3	0.540	0.963	after 4 cuts
7	1	0.481	0.969	after 5 cuts
7	2	0.303	0.915	after 6 cuts
8	1	0.201	0.984	after 6 cuts
8	2	0.249	0.980	after 5 cuts
9	1	0.271	0.965	after 5 cuts

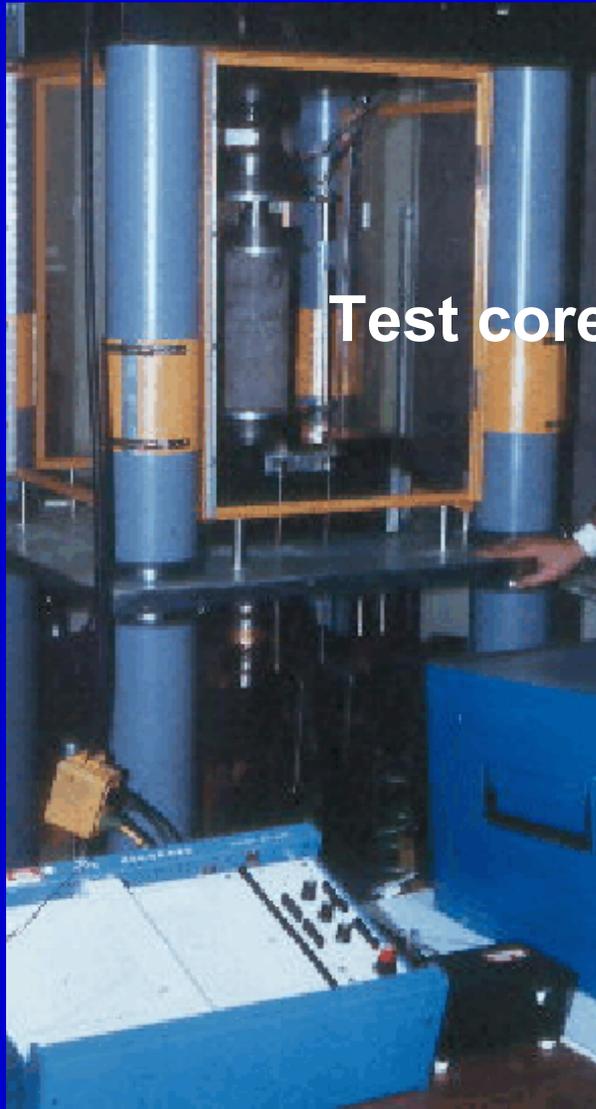
Average slope = 0.36
 Standard deviation = 0.12
 Coefficient of variation = 33%



How does one get to a
satisfactory correlation?

APPROACH to the PROJECT

- Mine measurements for monitoring (safety) and for data to compare with model calculations.
- Laboratory testing for rock properties, elastic moduli and strengths.
- FE modeling: stress, strain, displacements.
- Model calibration against displacements and extent of yield zones (constrained by anchor loss), elastic-plastic scale factors.
- Use of calibrated model for parametric design analysis.



Laboratory Testing



Laboratory σ - ϵ testing (anisotropic)

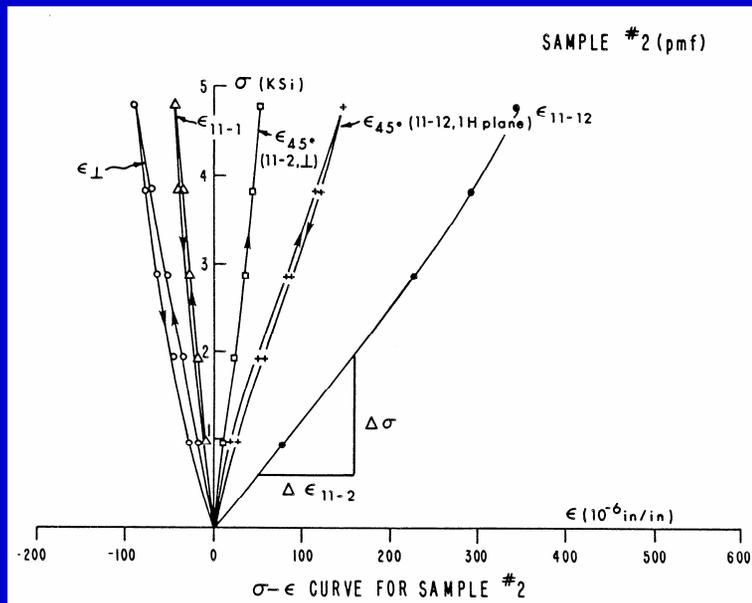
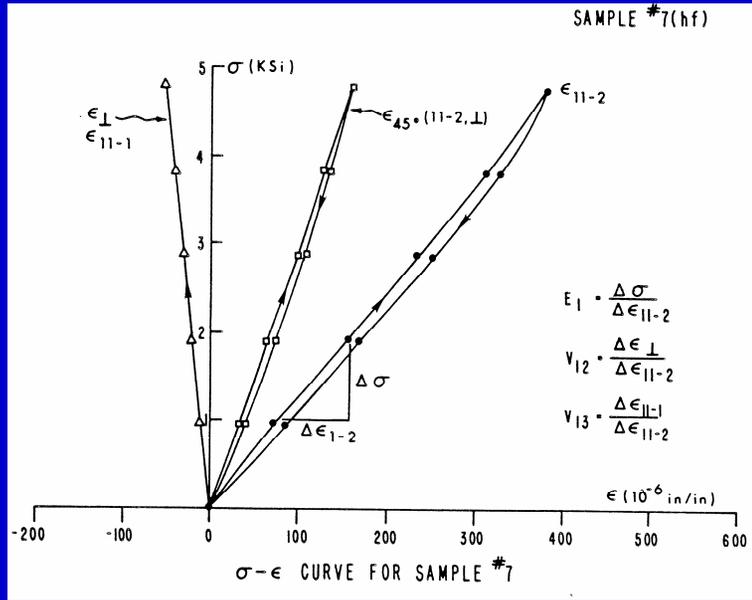


Figure 58. - Poorman formation laboratory stress strain curves.

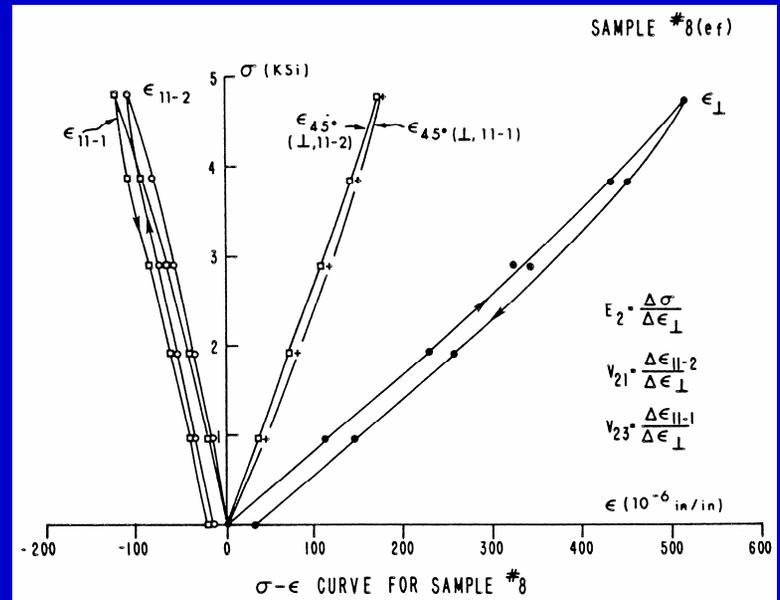


TABLE 21. - Laboratory anisotropic rock properties

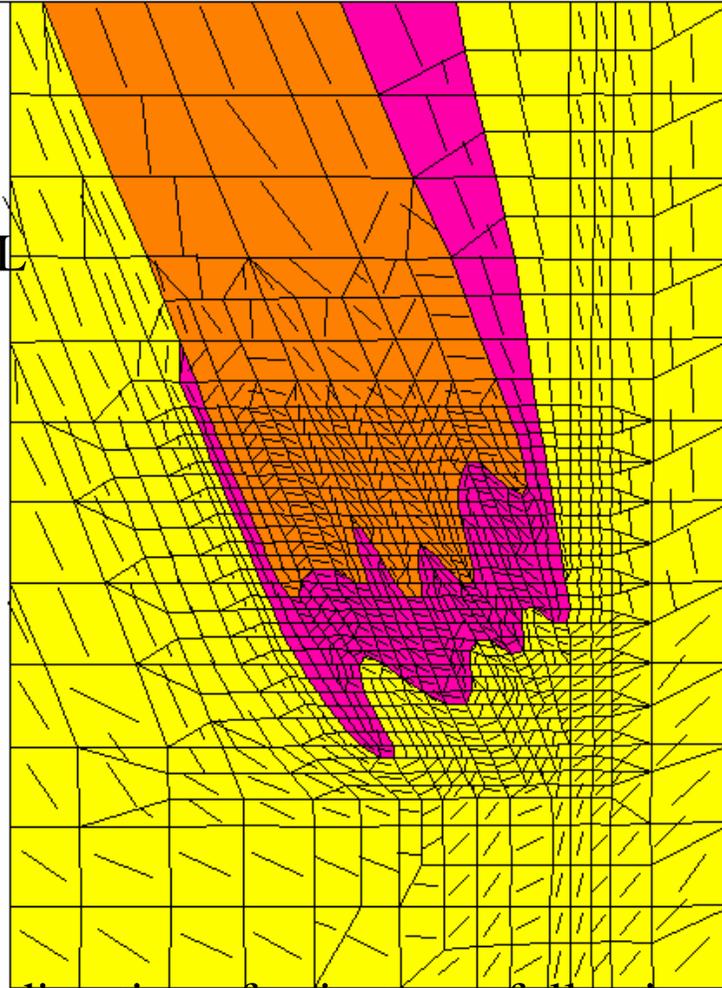
Property*	Homestake Formation	Poorman Formation	Ellison Formation
E_1	12.8×10^6	13.5×10^6	13.0×10^6
E_2	9.3×10^6	7.2×10^6	9.2×10^6
E_3	9.0×10^6	13.7×10^6	11.0×10^6
ν_{12}	0.14	0.23	0.20
ν_{23}	0.18	0.15	0.17
ν_{31}	0.19	0.22	0.15
G_{12}	4.8×10^6	3.8×10^6	4.6×10^6
G_{23}	3.9×10^6	3.9×10^6	4.2×10^6
G_{31}	4.3×10^6	5.6×10^6	5.1×10^6
C_1	20,150	13,630	11,340
C_2	11,550	10,000	11,410
C_3	13,270	12,270	8,150
T_1	1,380	2,990	2,350
T_2	1,140	820	590
T_3	1,920	1,910	1,650
R_1	2,050	1,500	1,150
R_2	2,470	2,800	2,120
R_3	2,100	1,280	1,250

*1- and 3-direction are parallel to the schistosity; the 2-direction is perpendicular to the schistosity. All units are psi (except for Poisson's ratios)

Deep, wide vein mine – well developed foliation



VERTICAL
SECTION



Colored portion
is 1350 ft wide
x 1830 ft high.

Local direction of anisotropy following folding
of the Poorman (yellow), Homestake (pink)
and Ellison (orange) formations.

TABLE 13. - In situ stress measurements

Principal stresses and direction

<u>Source</u>	<u>Stress*</u>	<u>Magnitude</u>	<u>Bearing</u>	<u>Dip**</u>
Bond (1970) 6200 Level	Major	8,000 psi	--	vertical
	Intermediate	5,200	N50E	0
	Minor	2,900	N40W	0
Hooker (1972) 3050 Level	Major	3,051	--	vertical
	Intermediate	3,687	N43E	0
	Minor	1,845	N47W	0
6200 Level	Major	7,720	--	vertical
	Intermediate	5,349	N30E	0
	Minor	3,624	N60W	0
USBM (1984)** 7400 Level	Major	7,985	N83W	53°
	Intermediate	3,411	N08W	71°
	Minor	1,927	N61E	43°

Vein Stresses

<u>Source</u>	<u>Dip Direction</u>		<u>Strike Direction</u>		<u>Vertical</u>	<u>Vertical Shear</u>	<u>Vein Shear</u>
Hooker (3050 L)	N43E	3,687 psi	N47W	1,845 psi	3,051 psi	0/0	0
(6200 L)	N30E	5,349	N60W	3,624	7,720	0/0	0
Bond (6200 L)	N50E	5,200	N40W	2,900	8,000	0/0	0
USBM (7400 L)	N45E	5,496	N45W	4,220	4,237	1925/2064	938

* compression positive

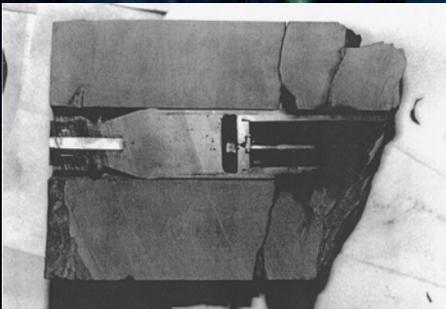
** down positive

In situ stress measurement summary in terms of principal stresses and directions.

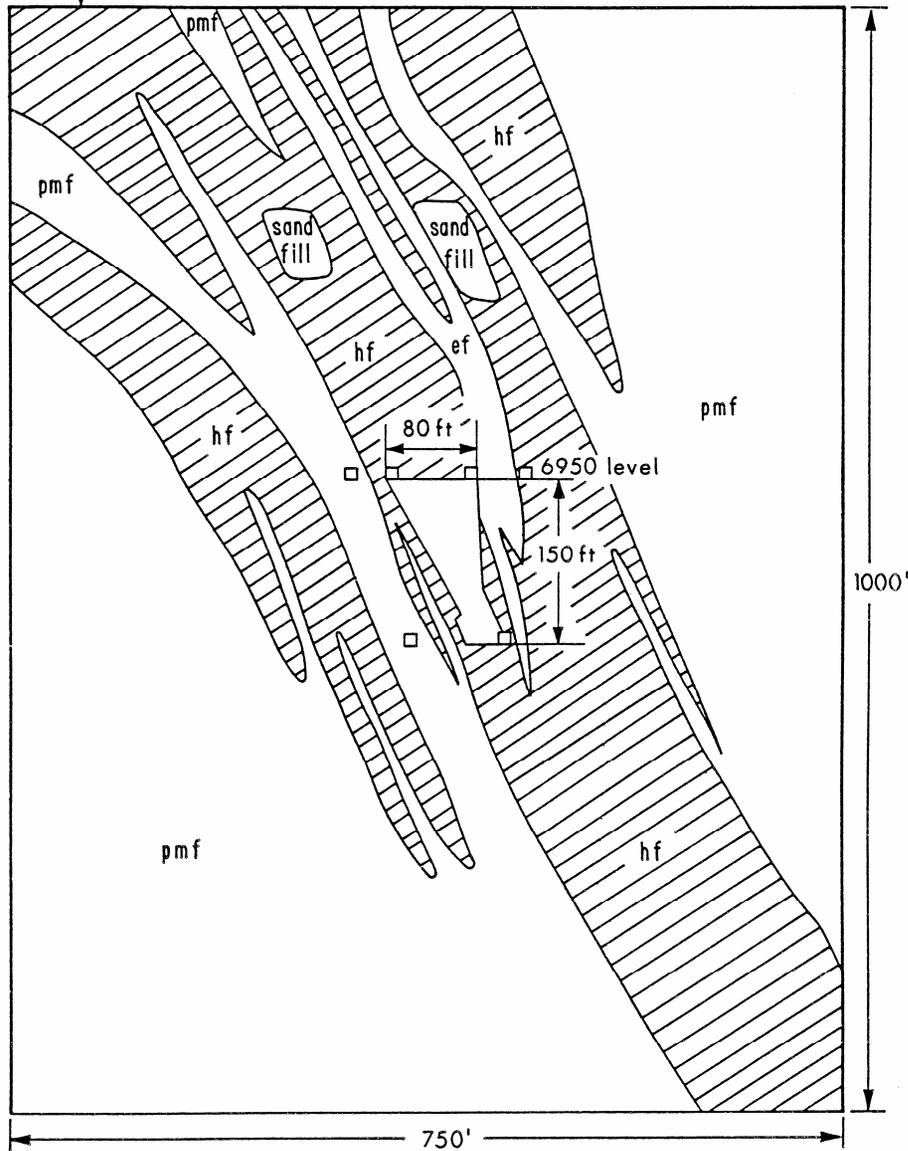
Stress Measurement



HI-cells



Depth = 6450'

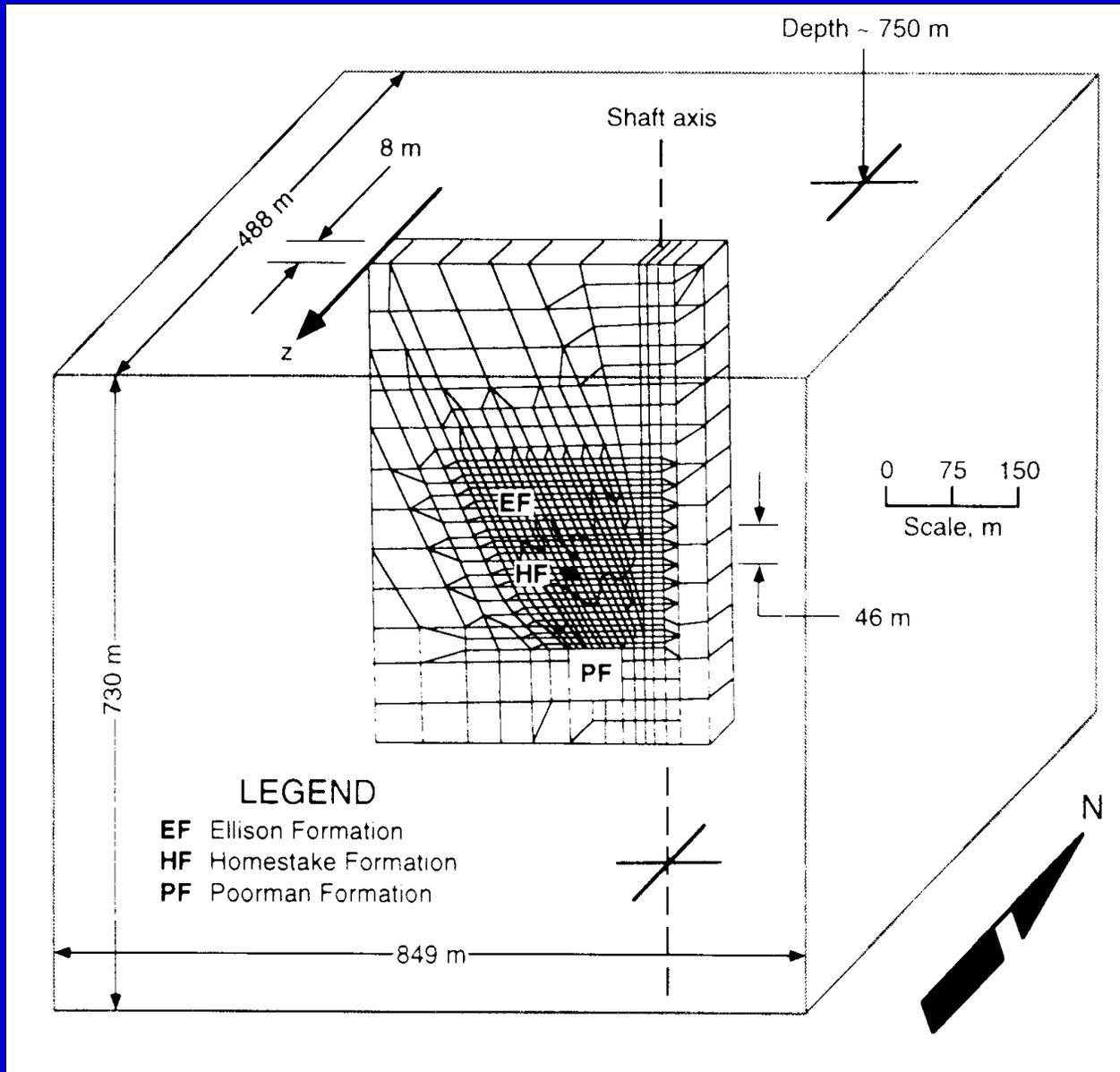


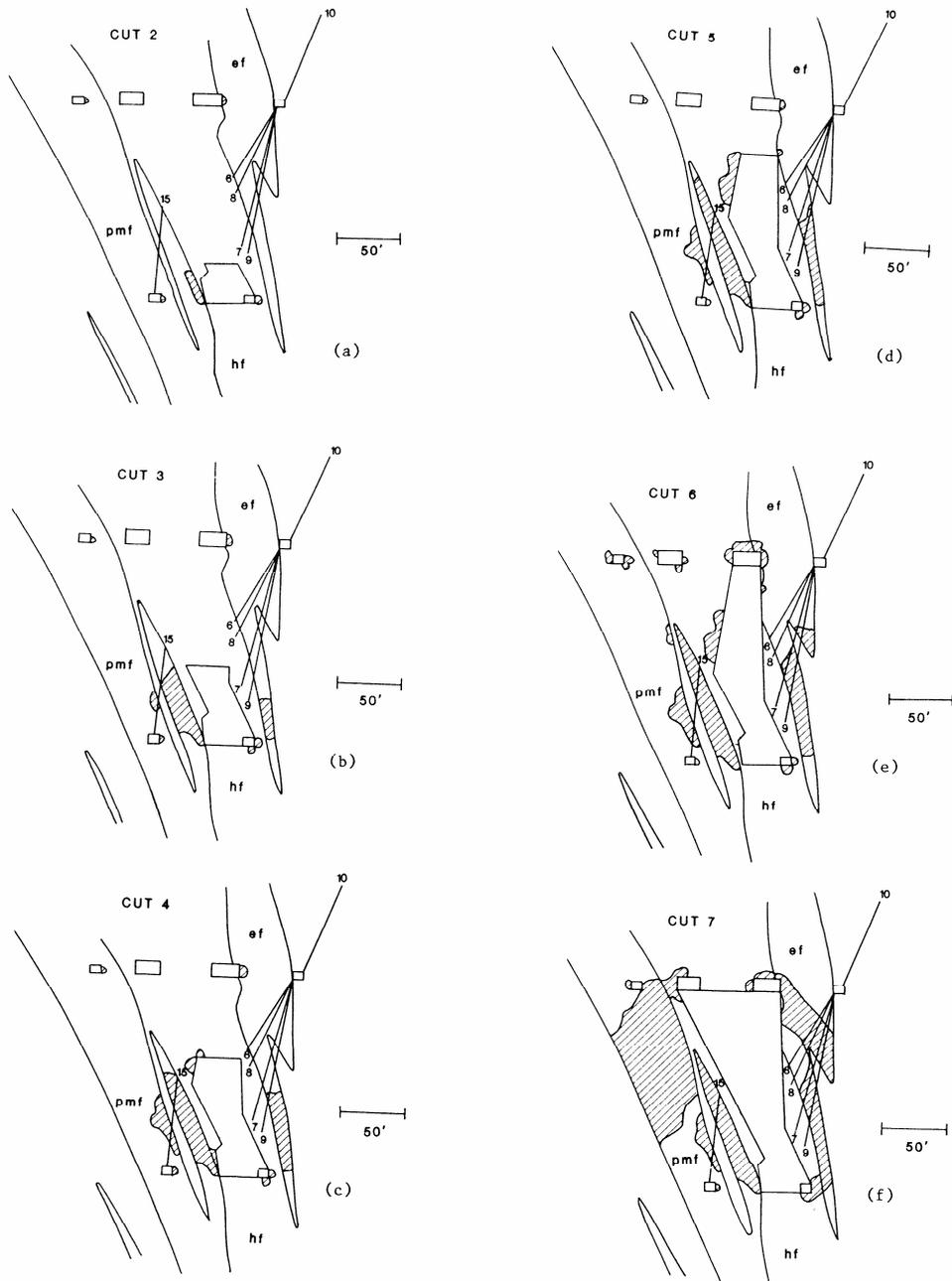
Panel 3 Cross Section

Outline of Geology
Stope Dimensions
FE Mesh Size

Figure 62. - Homestake Mine study stope region, geometry and geology in vertical section looking north.

OVERALL 3D VIEW OF MESH

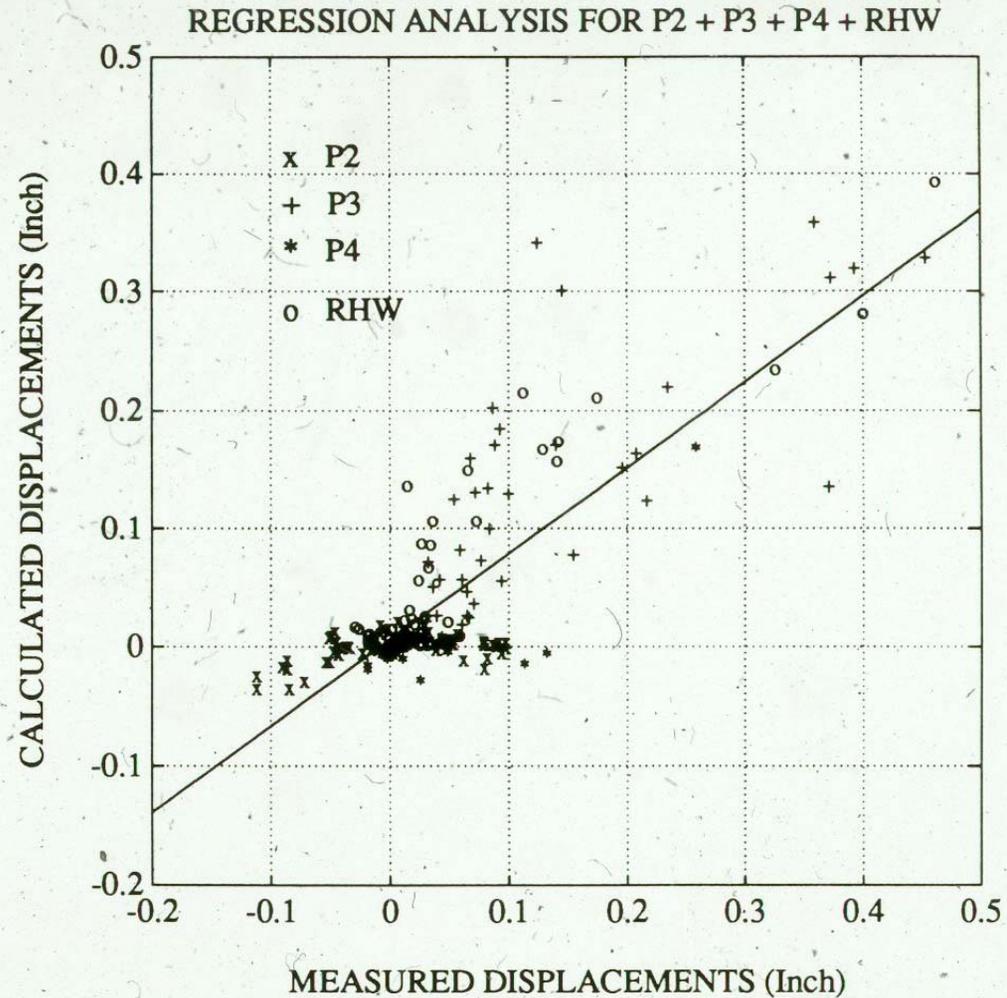
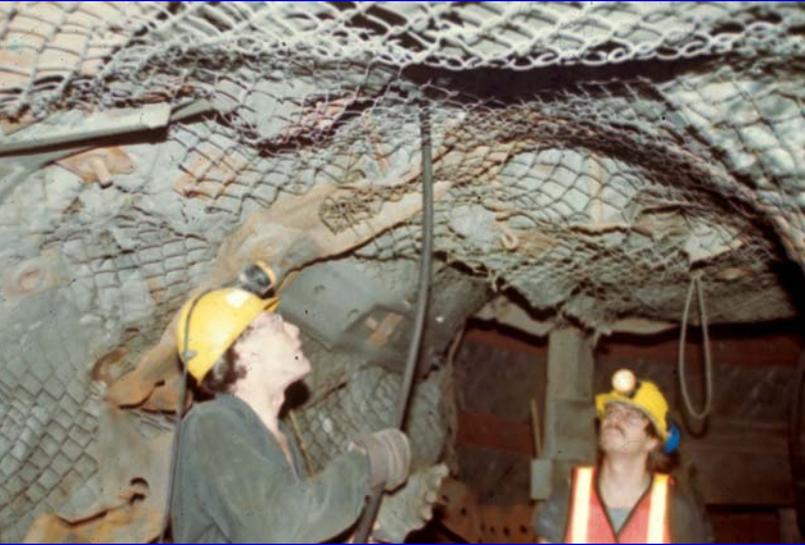


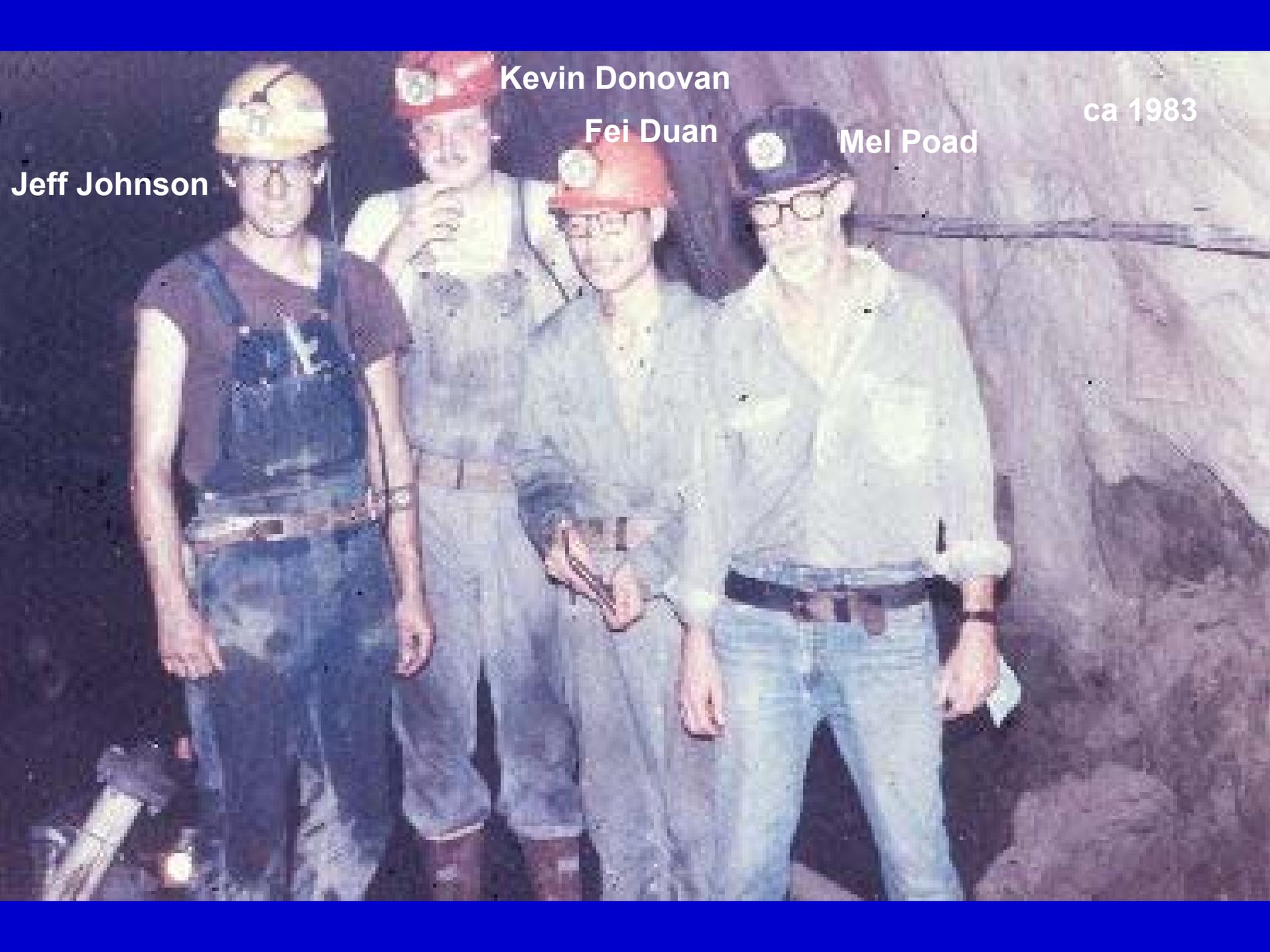


Finite element excavation sequence (seven cuts shown).

FIG. 9. FINITE ELEMENT SIMULATION OF THE MINING SEQUENCE. SHADED REGION SHOWS EVOLUTION OF THE YIELD ZONE. DEVELOPMENT OCCURS ON COMPUTER CUT 1.

INSTRUMENTATION and MINE MEASUREMENTS of DISPLACEMENTS





Jeff Johnson

Kevin Donovan

Fei Duan

Mel Poad

ca 1983

Main Conclusion

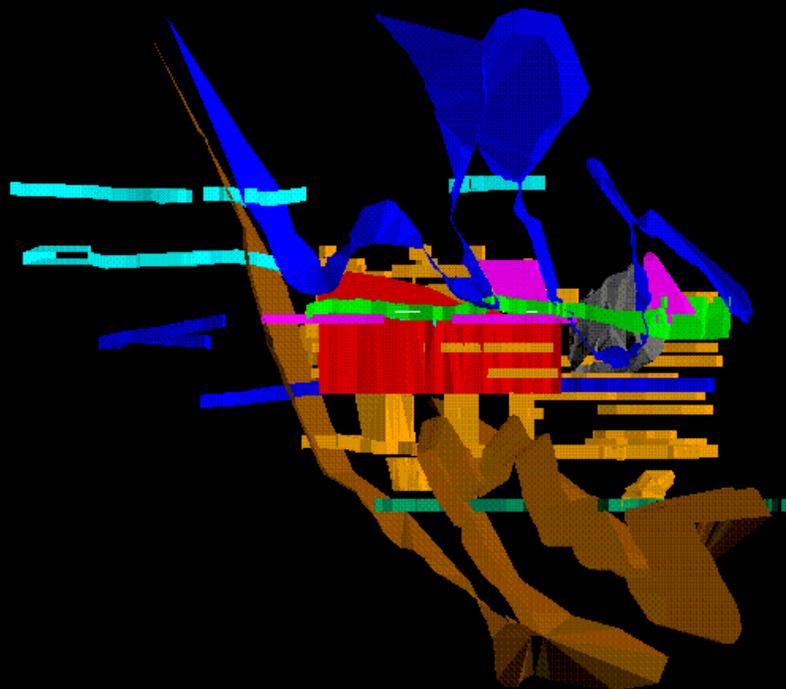
With adequate site investigation, large caverns can be reliably engineered and excavated at Homestake.

“site investigation”

- Exploration drill holes for **geology** and **geologic structure** (mapping).
- Drill core for laboratory testing to determine rock properties (**moduli, strengths**).
- *In situ* stress measurements.

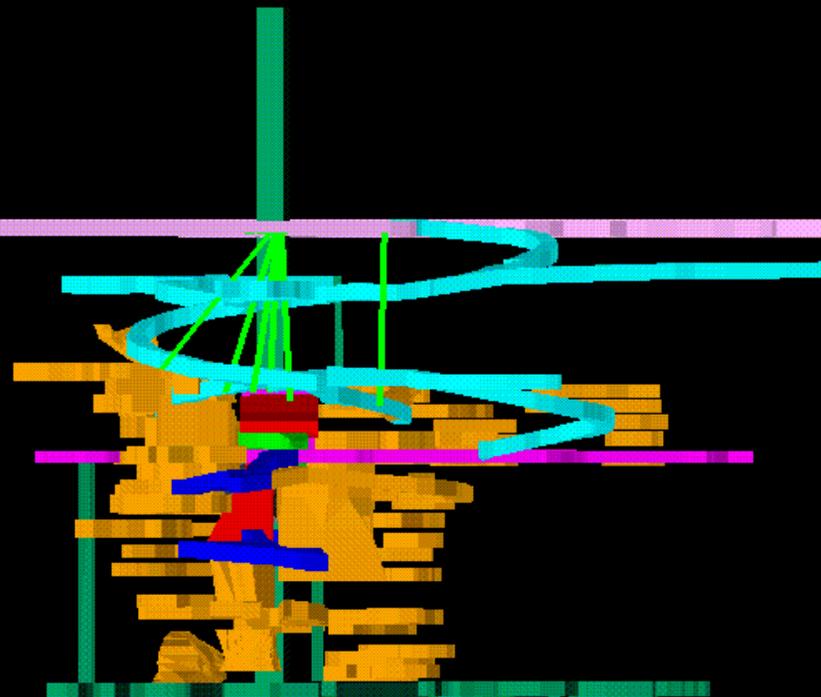
Suggestion: Start “small” with a pilot-scale excavation.

- To confirm site exploration data.
- To allow for monitoring with MPBX's, etc.
- To allow for FE model calibration leading to full-scale design.

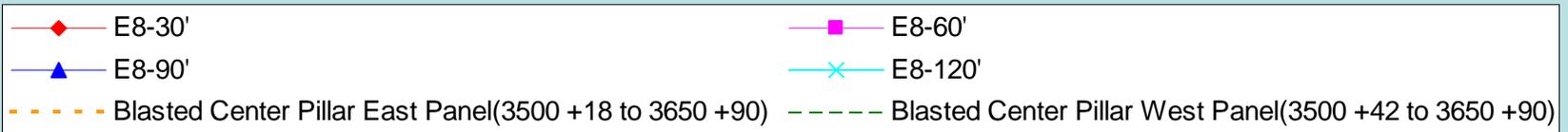
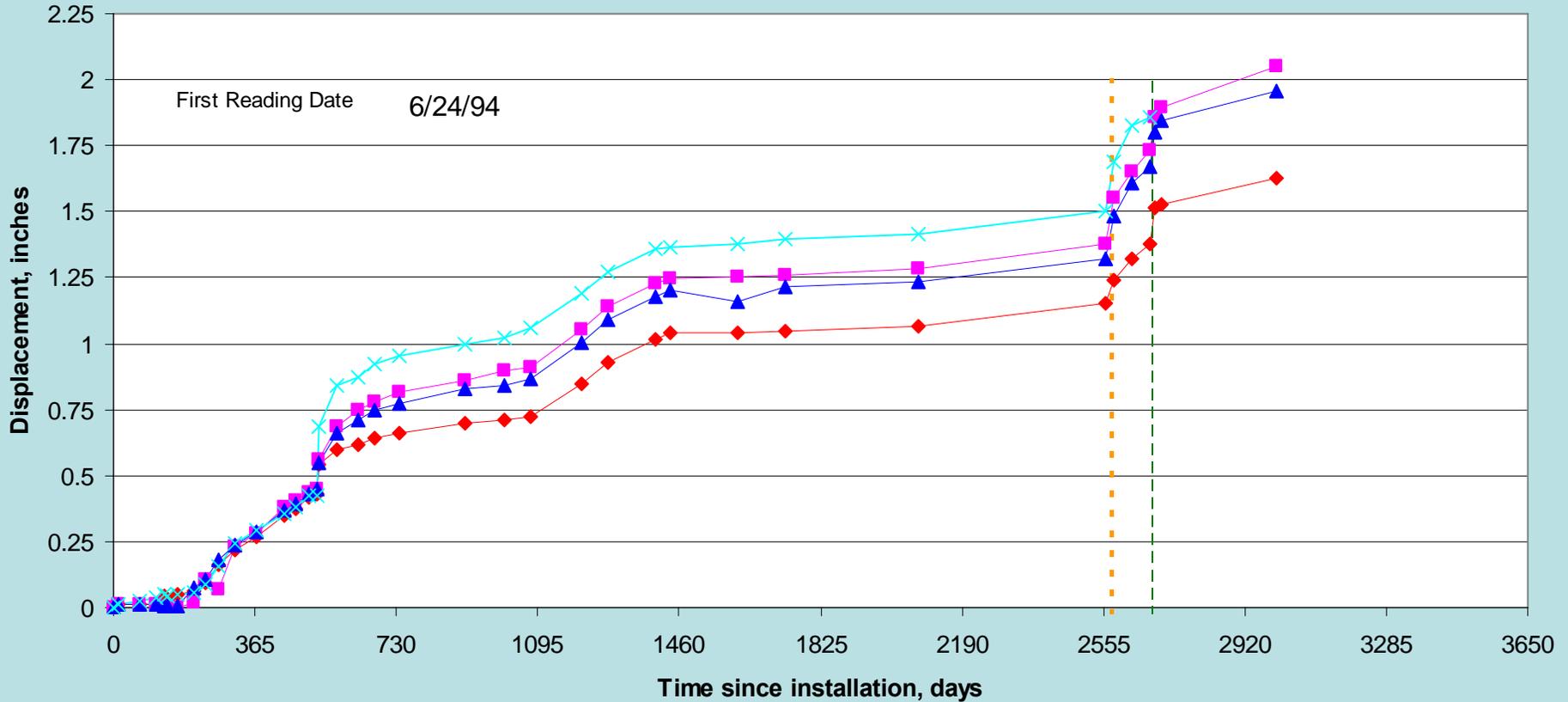


Ross Shaft pillar
view using mine
planning software
(Homestake fold
limbs in brown.)

Four point MPBX's
near Ross Shaft pillar
(Hole collars on 3350 L)



**Ext 8: Displacement
Ross Pillar
3350 Level**



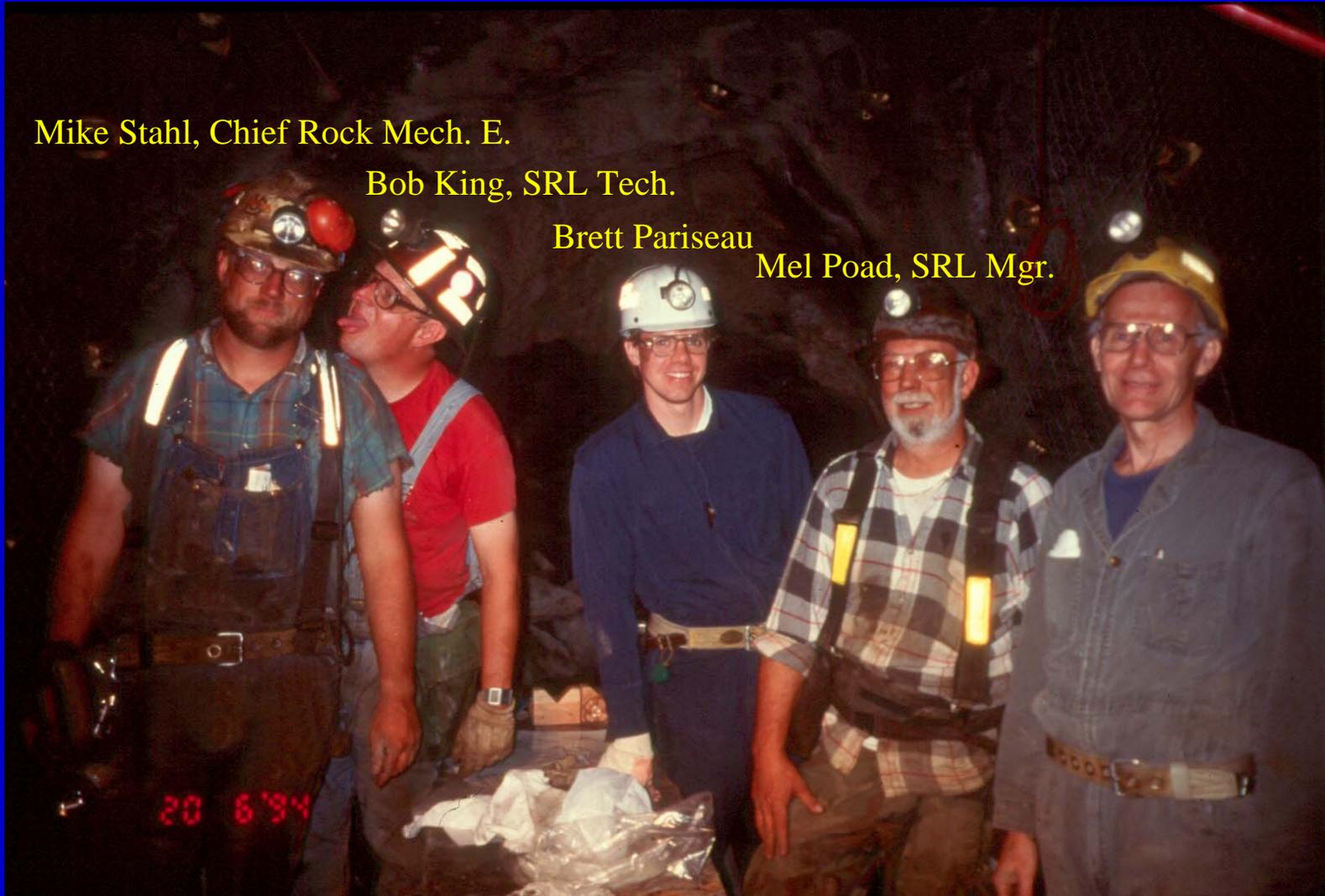
DAY'S END (June, 1994)

Mike Stahl, Chief Rock Mech. E.

Bob King, SRL Tech.

Brett Pariseau

Mel Poad, SRL Mgr.



NUSL offers *unique* opportunities in a variety of disciplines – controlled experiments on an exceptionally large rock mass – over 350 miles of “tunnels” for access and instrumentation.

Rock mass scale (whole mine experiments)	-10^3 m
Stope, cavity scale	-10^2 m
Tunnel, shaft scale	-10^1 m
Borehole, “laboratory” scale	-10^{-1} m
Grain, sub-lab scale	-10^{-3} m

CONNECTIONS, RELATIONS, INTERACTIONS,
INFORMATION EXCHANGE BTWN SCALES?



HOMESTAKE GOLD MINE
THE AMERICAS' LARGEST
SURFACE TOURS
MAY THRU OCTOBER
600 FT. AHEAD

THIS IS THE PLACE!

Thank you!