



Stillwater Mining Company

Narrow Vein Mining Methods and Geologic
Grade-Control on the JM-Reef Pd/Pt Deposit

Sarah Jensen



J-M Reef PGM Production

Pd/Pt (3.4:1) are our primary target elements, hosted as sulfide mineralization

Hydrogen 1 H 1.0079	Helium 2 He 4.0026																	
Lithium 3 Li 6.941	Beryllium 4 Be 9.0122											Boron 5 B 10.811	Carbon 6 C 12.011	Nitrogen 7 N 14.0064	Oxygen 8 O 15.999	Fluorine 9 F 18.998	Neon 10 Ne 20.180	
Sodium 11 Na 22.989	Magnesium 12 Mg 24.305											Aluminum 13 Al 26.982	Silicon 14 Si 28.086	Phosphorus 15 P 30.974	Sulfur 16 S 32.06	Chlorine 17 Cl 35.453	Argon 18 Ar 39.948	
Potassium 19 K 39.098	Calcium 20 Ca 40.078	Scandium 21 Sc 44.956	Titanium 22 Ti 47.867	Vanadium 23 V 50.942	Chromium 24 Cr 51.996	Manganese 25 Mn 54.938	Iron 26 Fe 55.845	Cobalt 27 Co 58.933	Nickel 28 Ni 58.693	Copper 29 Cu 63.546	Zinc 30 Zn 65.38	Gallium 31 Ga 69.723	Germanium 32 Ge 72.61	Arsenic 33 As 74.922	Selenium 34 Se 78.96	Bromine 35 Br 79.904	Krypton 36 Kr 83.80	
Rubidium 37 Rb 85.468	Strontium 38 Sr 87.62	Yttrium 39 Y 88.906	Zirconium 40 Zr 91.224	Niobium 41 Nb 92.906	Molybdenum 42 Mo 95.94	Technetium 43 Tc [98]	Ruthenium 44 Ru 101.07	Rhodium 45 Rh 101.07	Palladium 46 Pd 106.32	Silver 47 Ag 107.87	Cadmium 48 Cd 112.41	Indium 49 In 114.82	Tin 50 Sn 118.71	Antimony 51 Sb 121.76	Tellurium 52 Te 127.6	Iodine 53 I 126.90	Xenon 54 Xe 131.29	
Cesium 55 Cs 132.91	Barium 56 Ba 137.33	* 57-70	Lanthanum 71 Lu 174.97	Hafnium 72 Hf 178.49	Tantalum 73 Ta 180.95	Tungsten 74 W 183.84	Rhenium 75 Re 186.21	Osmium 76 Os 190.23	Iridium 77 Ir 192.22	Platinum 78 Pt 195.08	Gold 79 Au 196.97	Mercury 80 Hg 200.59	Thallium 81 Tl 204.38	Lead 82 Pb 207.2	Bismuth 83 Bi 208.98	Polonium 84 Po [209]	Astatine 85 At [210]	Rn 86 Rn [222]
Francium 87 Fr [223]	Radium 88 Ra [226]	** 89-102	Lr 103	Rf 104	Db 105	Sg 106	Bh 107	Hs 108	Mt 109	Uun 110	Uuu 111	Uub 112	Uuq 114					

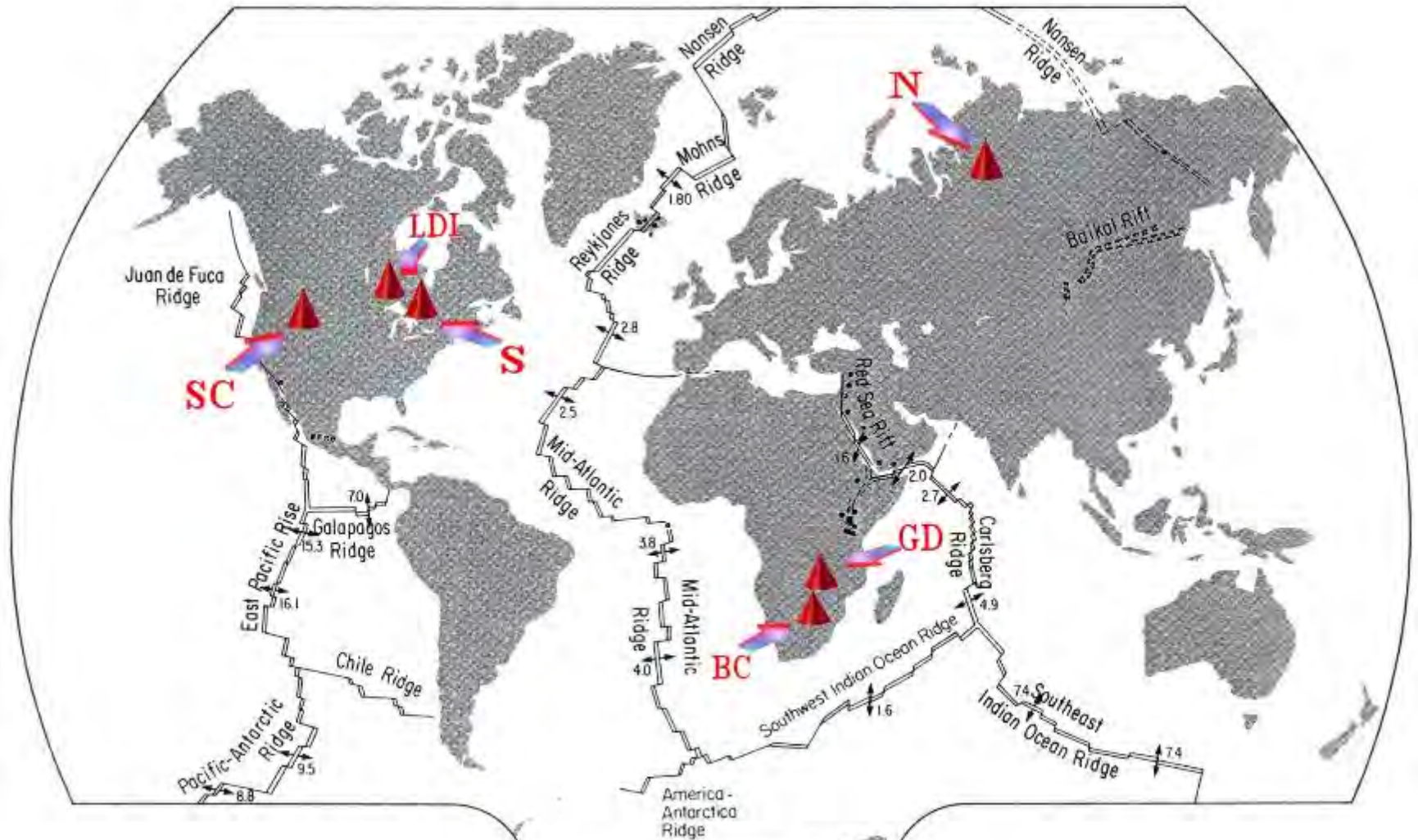
* Lanthanide series

Lanthanum 57 La 138.91	Cerium 58 Ce 140.12	Praseodymium 59 Pr 140.91	Neodymium 60 Nd 144.24	Promethium 61 Pm [145]	Samarium 62 Sm 150.36	Europium 63 Eu 151.96	Gadolinium 64 Gd 157.25	Terbium 65 Tb 158.93	Dysprosium 66 Dy 187.50	Holmium 67 Ho 164.93	Erbium 68 Er 167.26	Thulium 69 Tm 168.93	Ytterbium 70 Yb 173.04
Actinium 89 Ac [227]	Thorium 90 Th 232.04	Protactinium 91 Pa 231.04	Uranium 92 U 238.03	Neptunium 93 Np [237]	Plutonium 94 Pu [244]	Americium 95 Am [243]	Curium 96 Cm [247]	Berkelium 97 Bk [247]	Californium 98 Cf [251]	Einsteinium 99 Es [252]	Fermium 100 Fm [257]	Mendelevium 101 Md [258]	Nobelium 102 No [259]

** Actinide series

Byproducts: rhodium, copper, nickel, gold, silver

Worldwide PGM Production

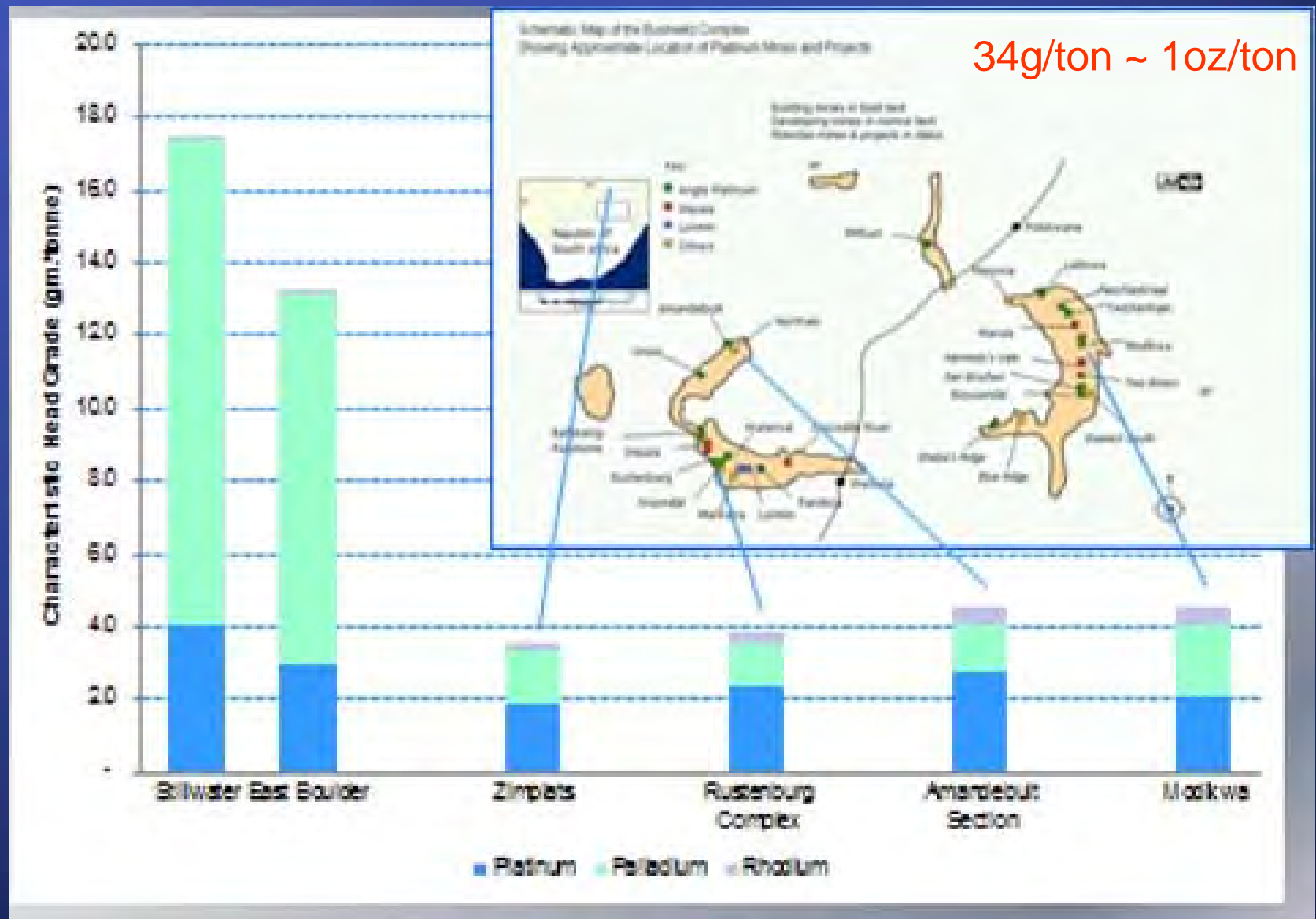


SMC is the only U.S. producer of PGMs and the largest primary producer outside of South Africa and the Russian Federation



Comparative PGM Ore Grades

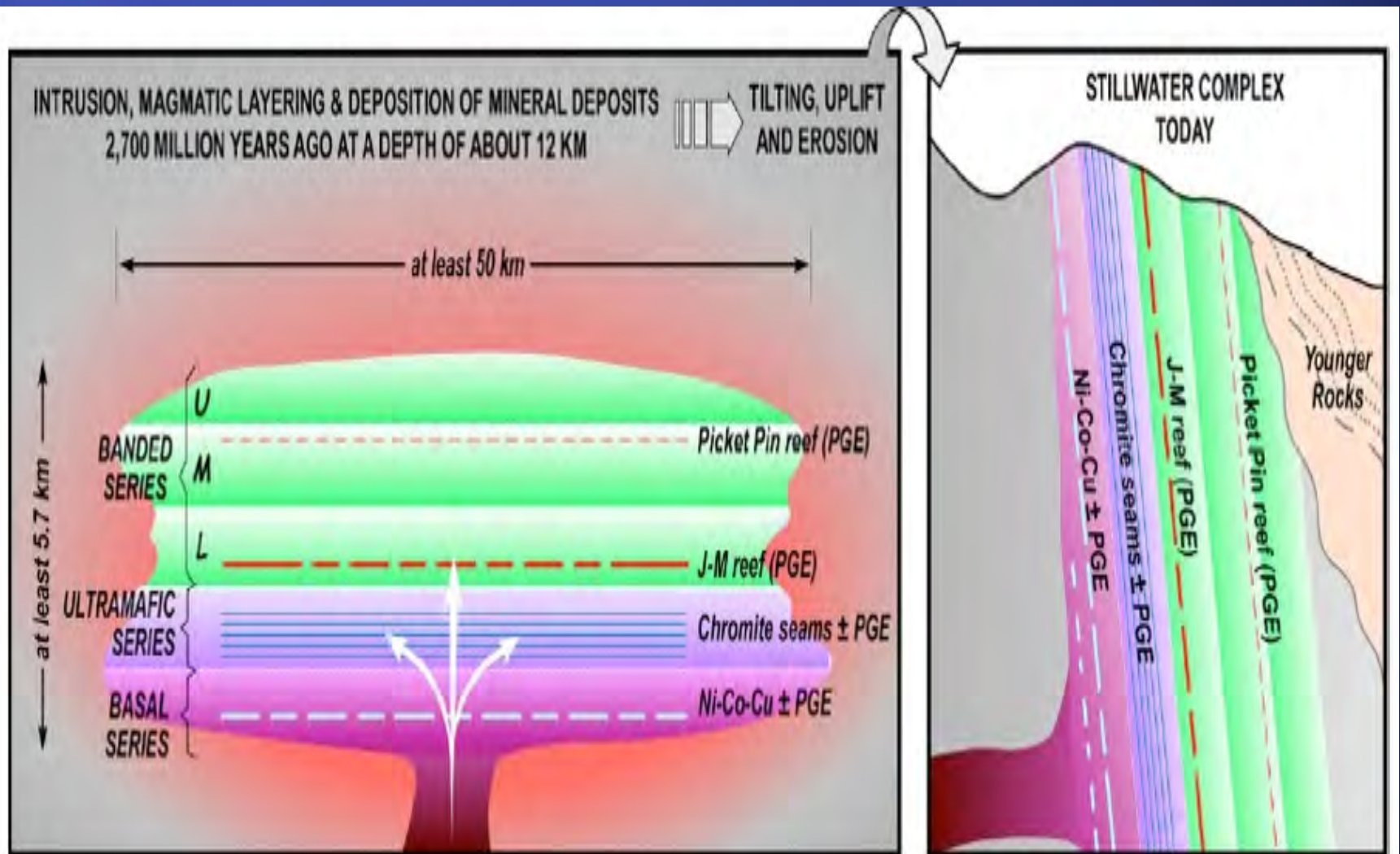
The J-M Reef is by far the highest grade PGM deposit of any known in the world!





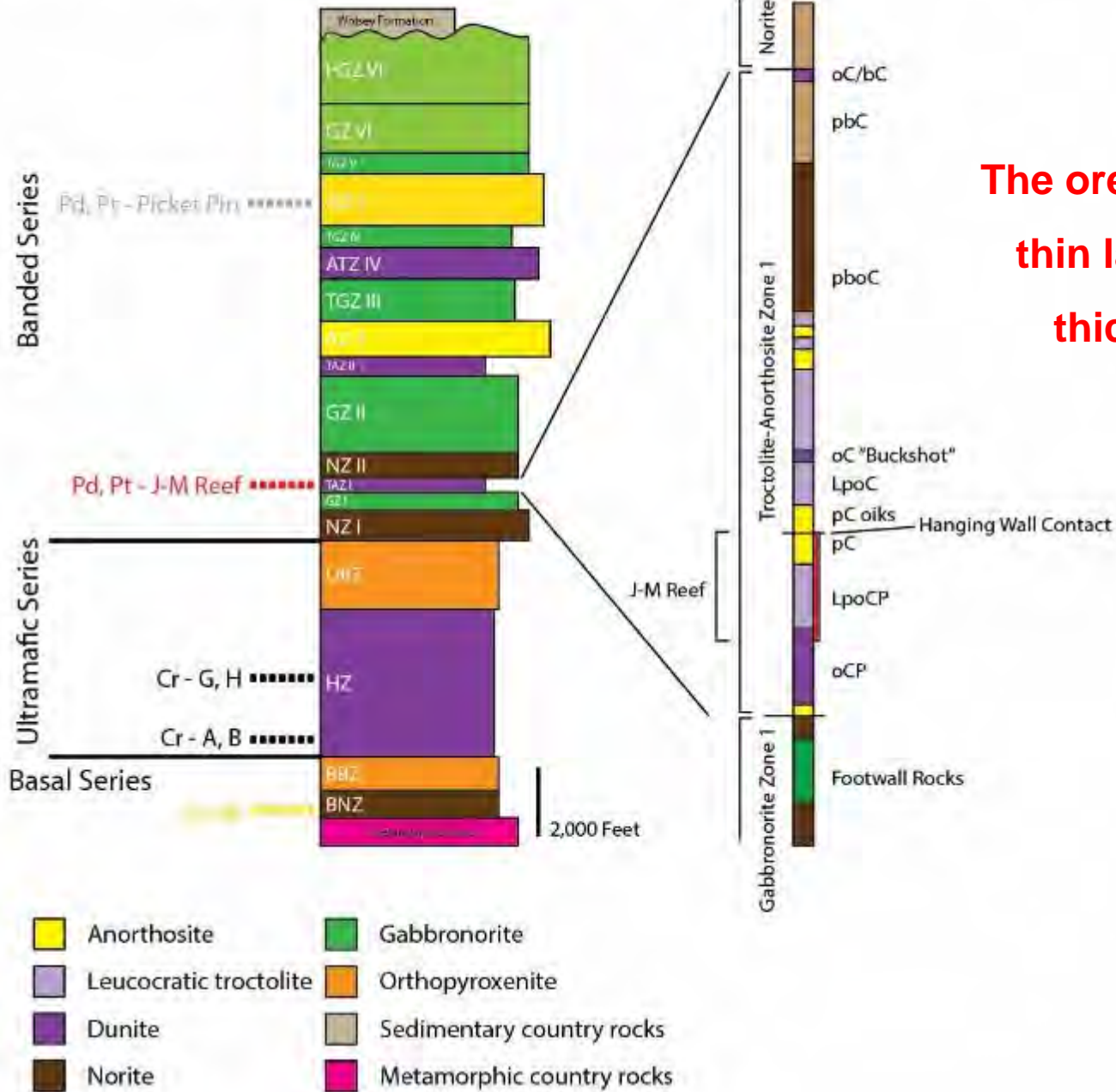
Stillwater Complex Emplacement

The 2.7by differentiated stratiform mafic to ultramafic intrusive igneous body was emplaced 6-9 miles under sedimentary rocks, resulting in a sub-horizontal inward-dipping cumulate layered lopolith





Stillwater Complex Stratigraphy



The ore zone is a very thin layer within a thick package of rocks

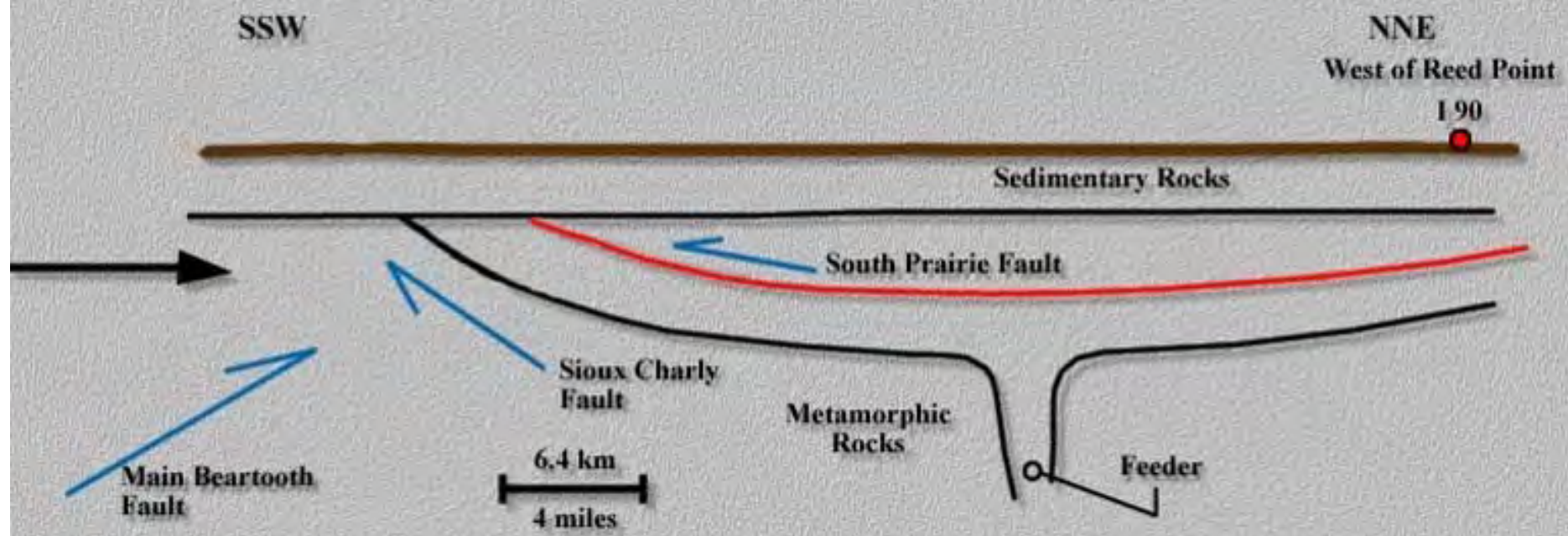
Original Stillwater Complex



- 2.7 Billion-Year-Old Intrusion
- Layering Develops Through Slow Cooling, Crystallization, and Other Processes
- Complex Subsequently Tilted and Eroded to Present Surface

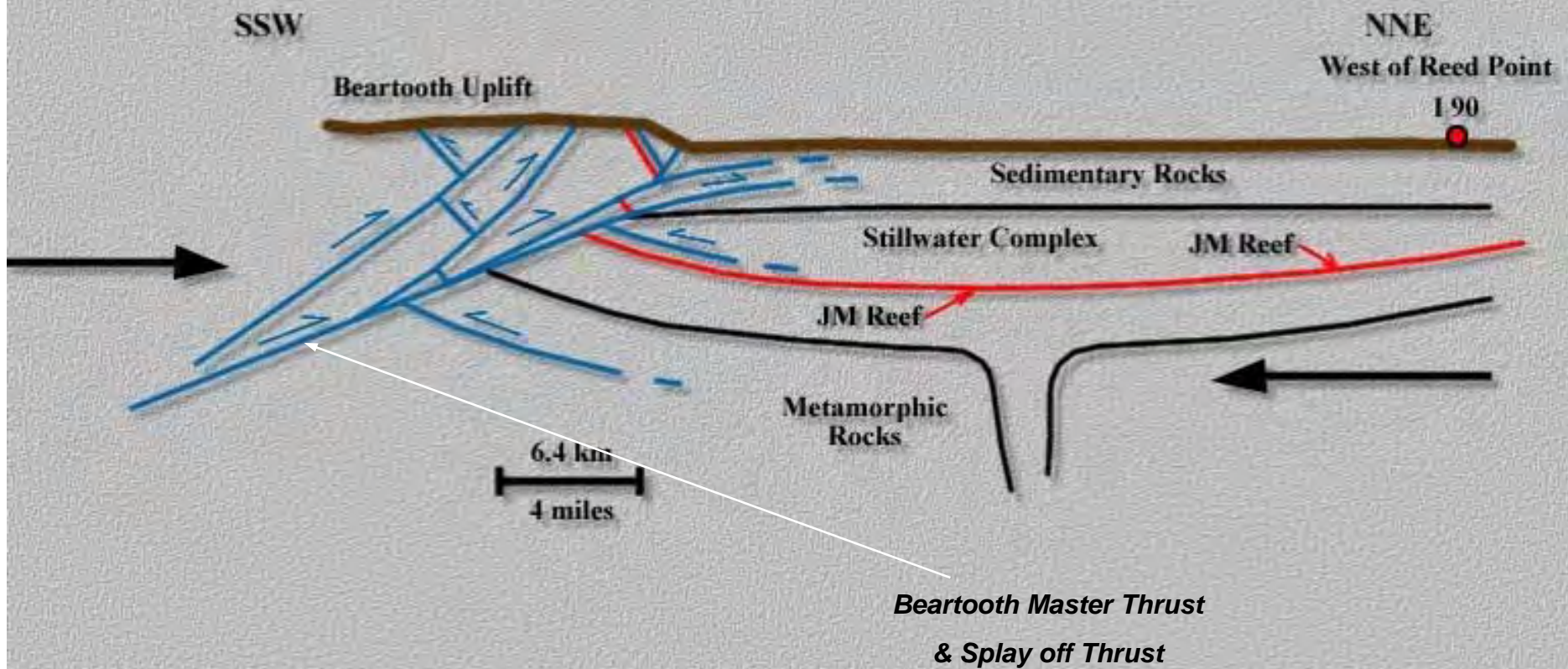
Beartooth Mountains Uplift: Sequence 1

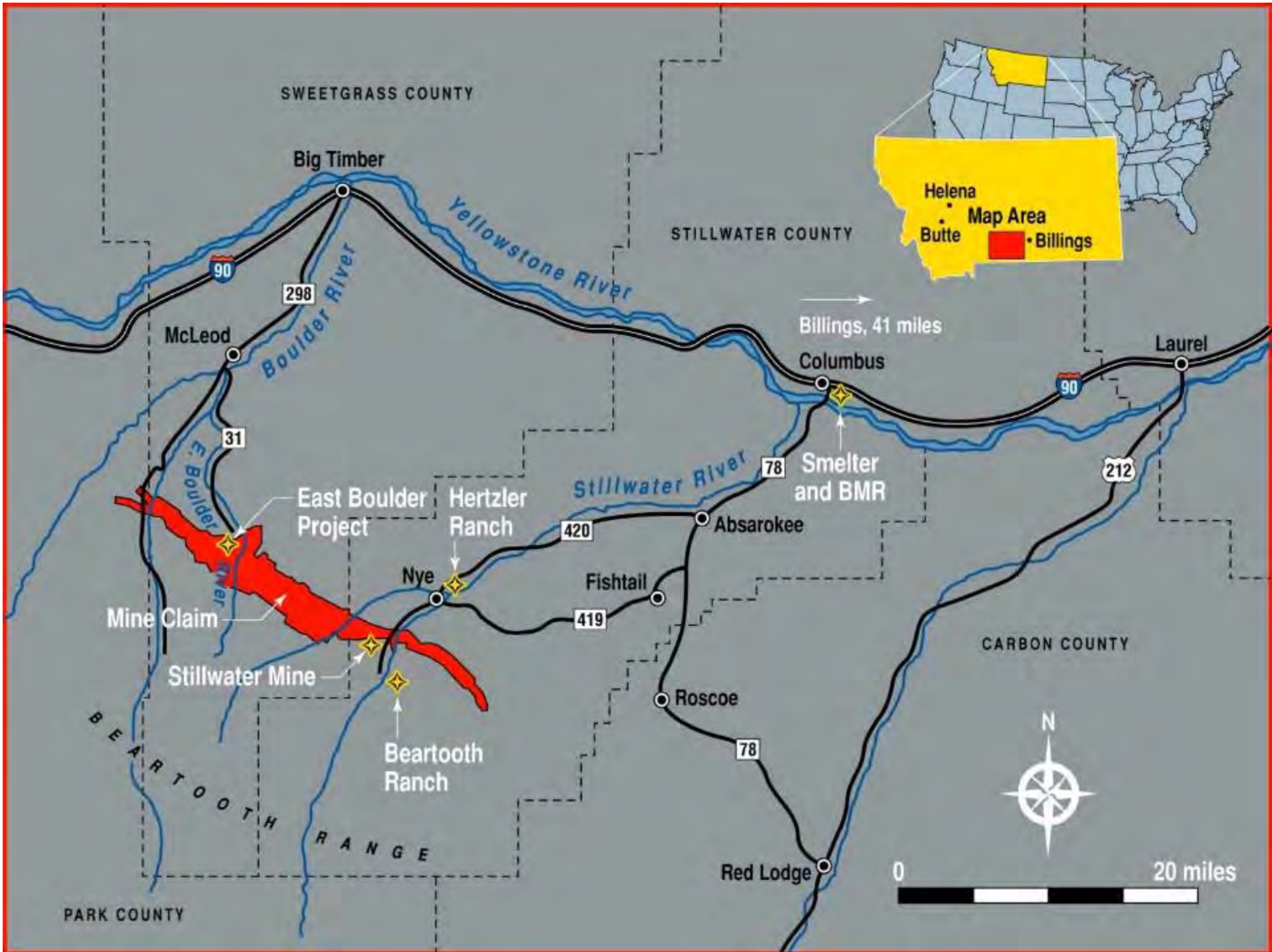
7500W Cross Section



Beartooth Mountains Uplift: Sequence 2

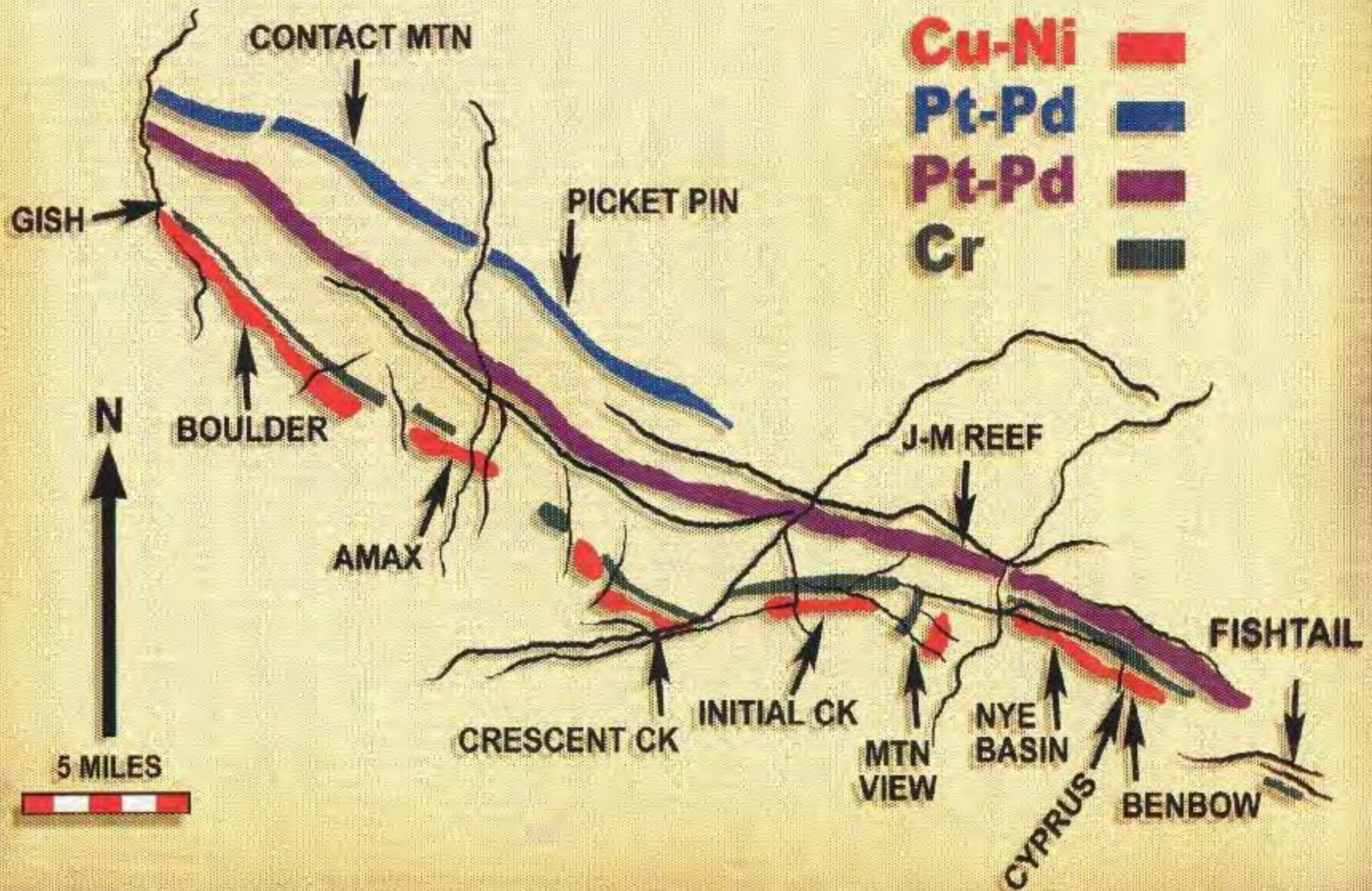
7500W Cross Section





STILLWATER PROJECT NYE, MONTANA

STILLWATER MINING COMPANY





Stillwater Complex Mining History

Nickel/Copper deposits

About **1883** by Skookum Joe Anderson, but may have been as early as 1860's

Chromite deposits

About **1890**, with first test mining at Little Rocky Creek (Benbow) by T.C. Benbow in 1905

Palladium/Platinum deposits

Pt/Pd-bearing minerals in 1936, but J-M Reef economically mineable layer in **1973** by Johns-Manville



Benbow Chromite Mining



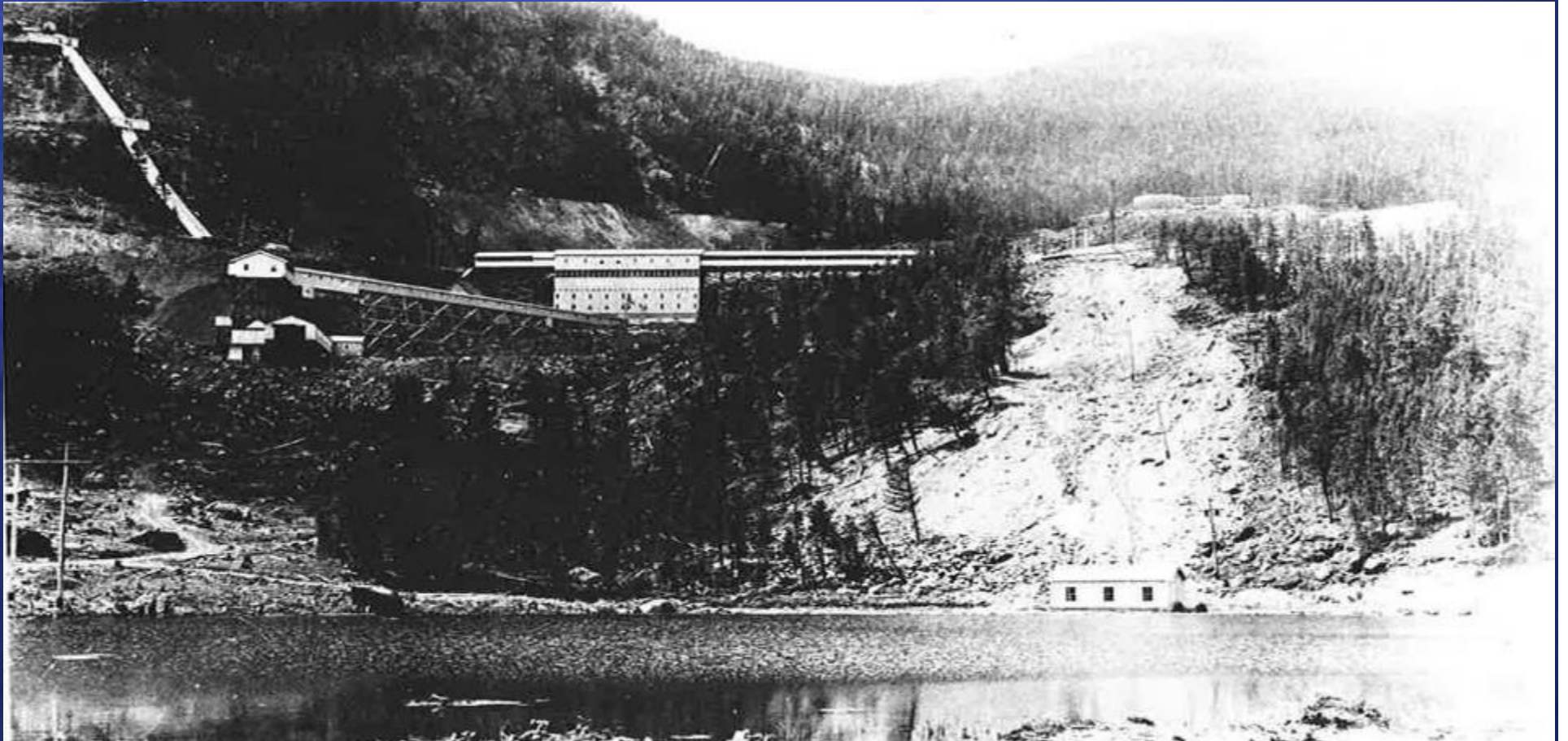


Benbow Chromite Mine Present Day





Mouat Mine-1943

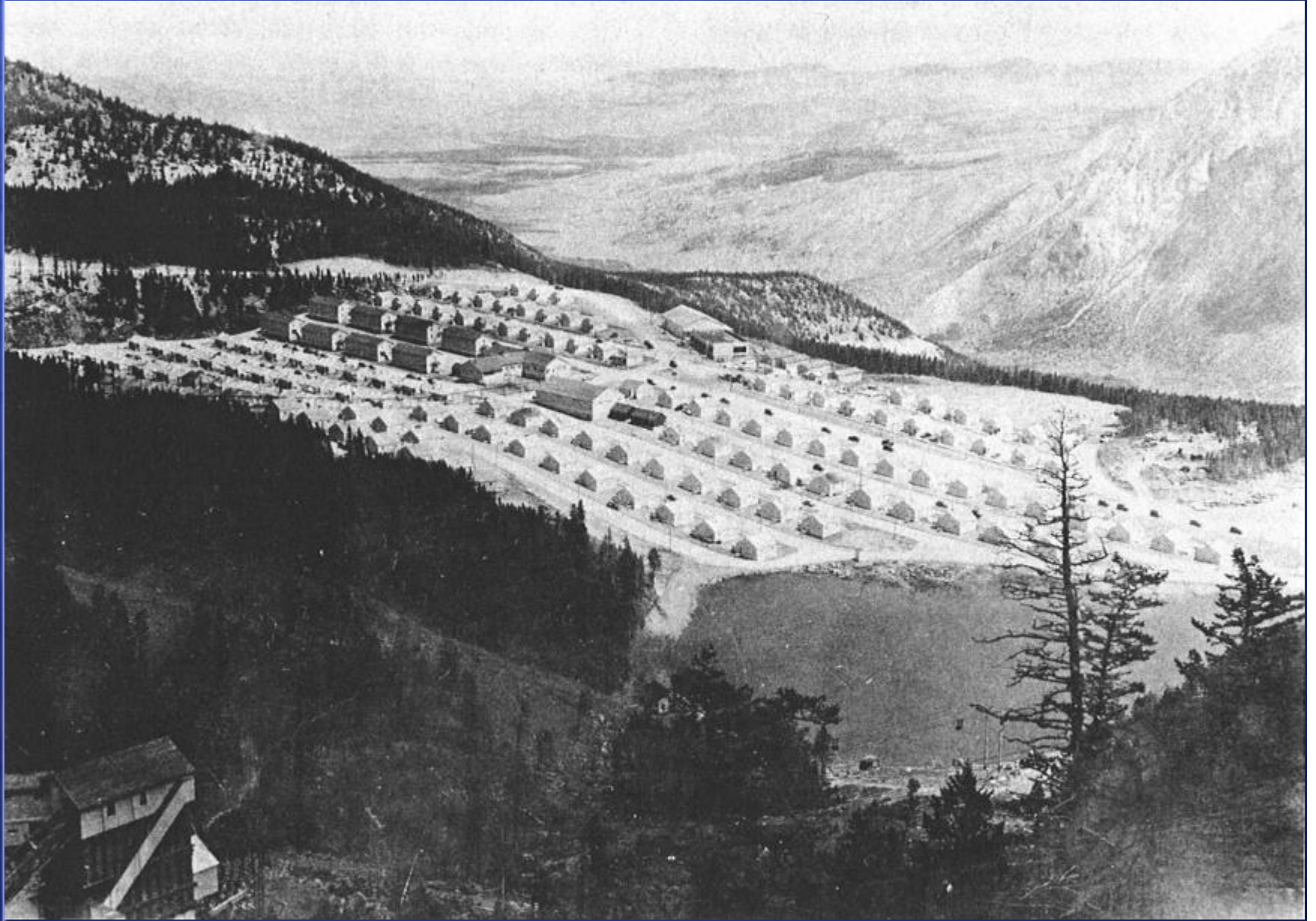


Moat Mine: Present Day





Lake Camp at the Mouat Mine





Lake Camp Present Day





J-M Reef Mineralogy

Major Minerals

- ◆ Plagioclase feldspar (bytownite)
- ◆ Orthopyroxene (bronzite)
- ◆ Clinopyroxene (augite)
- ◆ Olivine (chrysolite serpentized with magnetite)



Minor Minerals

- ◆ Sulfides: chalcopyrite pentlandite pyrrhotite
Associated Pd/Pt sulfides: braggite
cooperite vysotskite moncheite
- ◆ Phlogopite
- ◆ Chromite



PGM Ore Minerals

Pd Source	Pt Source	Mineral	Formula	Notes
80%	-	Pentlandite	$(\text{Fe, Ni})_9 \text{S}_8$	$\frac{3}{4}$ of the Palladium is in solid solution with Pentlandite
15%	-	Vysotskite	$(\text{Pd, Ni, Pt}) \text{S}$	2/3 of the Platinum and some of the Palladium is hosted as sulfides
	65%	Braggite	$(\text{Pt, Pd, Ni}) \text{S}$	
		Cooperite	$(\text{Pt, Pd, Ni}) \text{S}$	
-	25%	Isoferroplatinum	PtFe_3	$\frac{1}{4}$ of the Platinum is in a metallic alloy
5%	10%	Moncheite	$(\text{Pt, Pd}) (\text{Te, Bi})_2$	Some Platinum and Palladium are hosted as Telluride



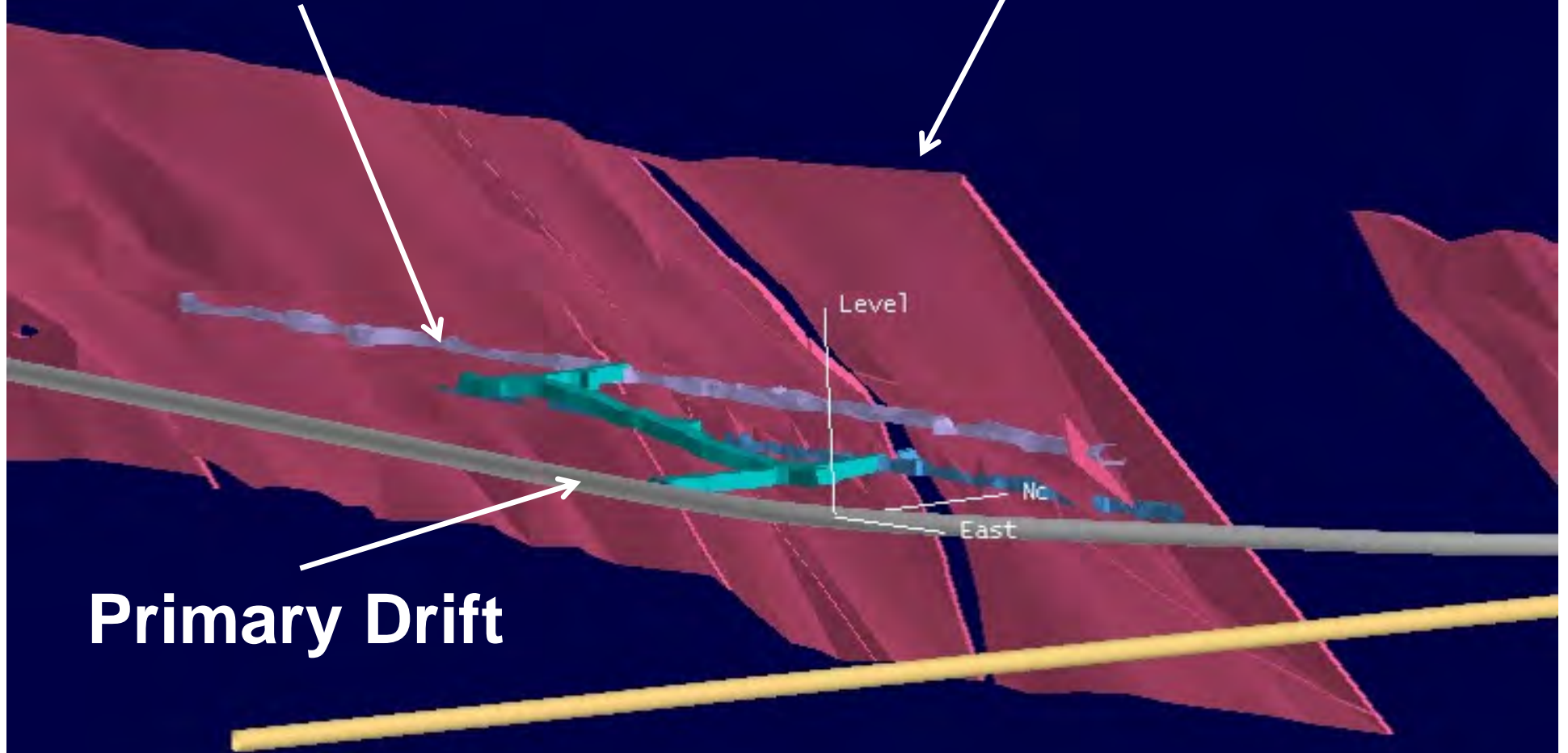
PGMs in base-metal pathfinder sulfides

Underground Development

Stope Mining

J-M Reef

Primary Drift

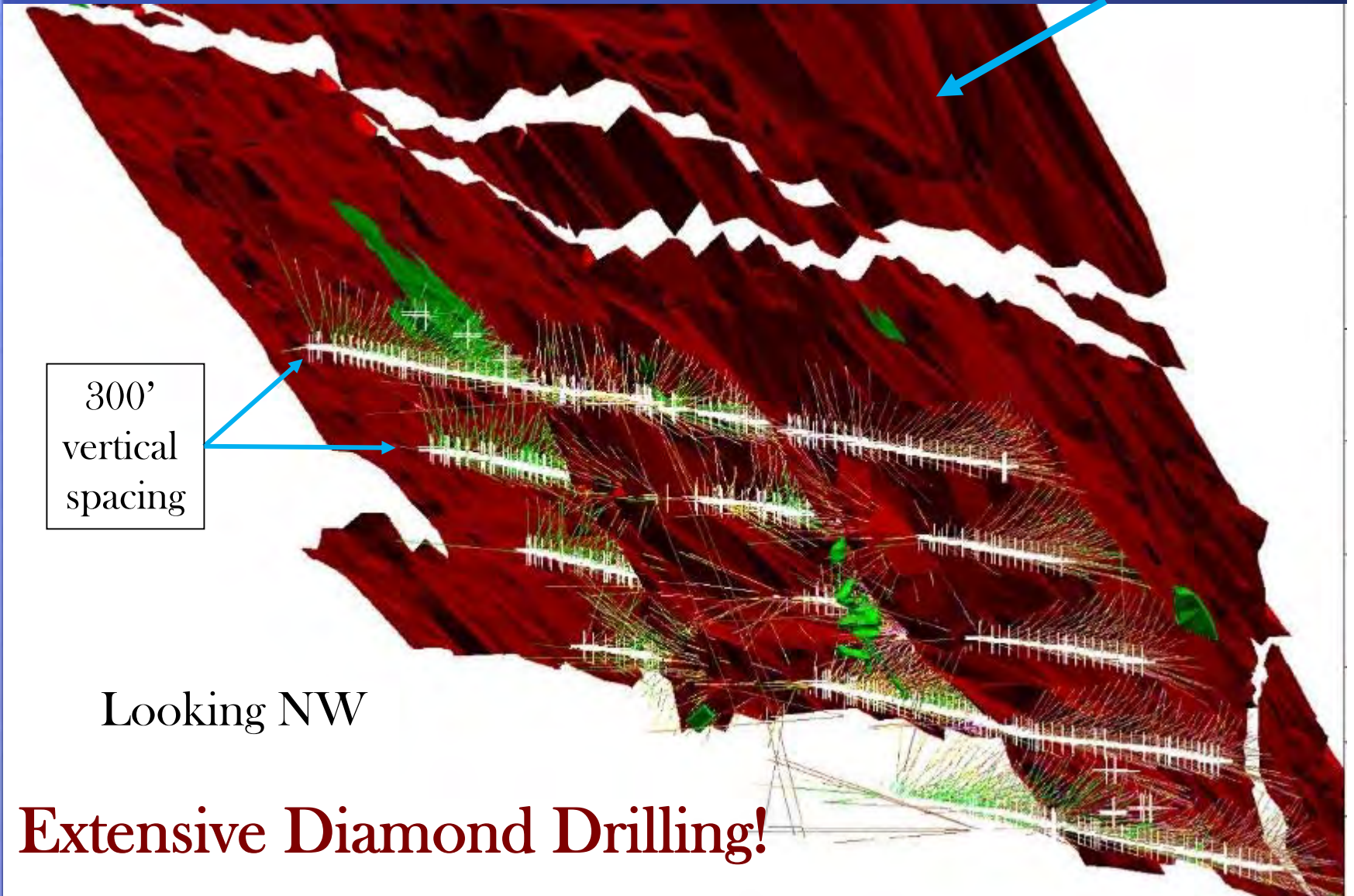




Diamond Drilling, Definition of the Ore

Performed at 50' centers along the FWL

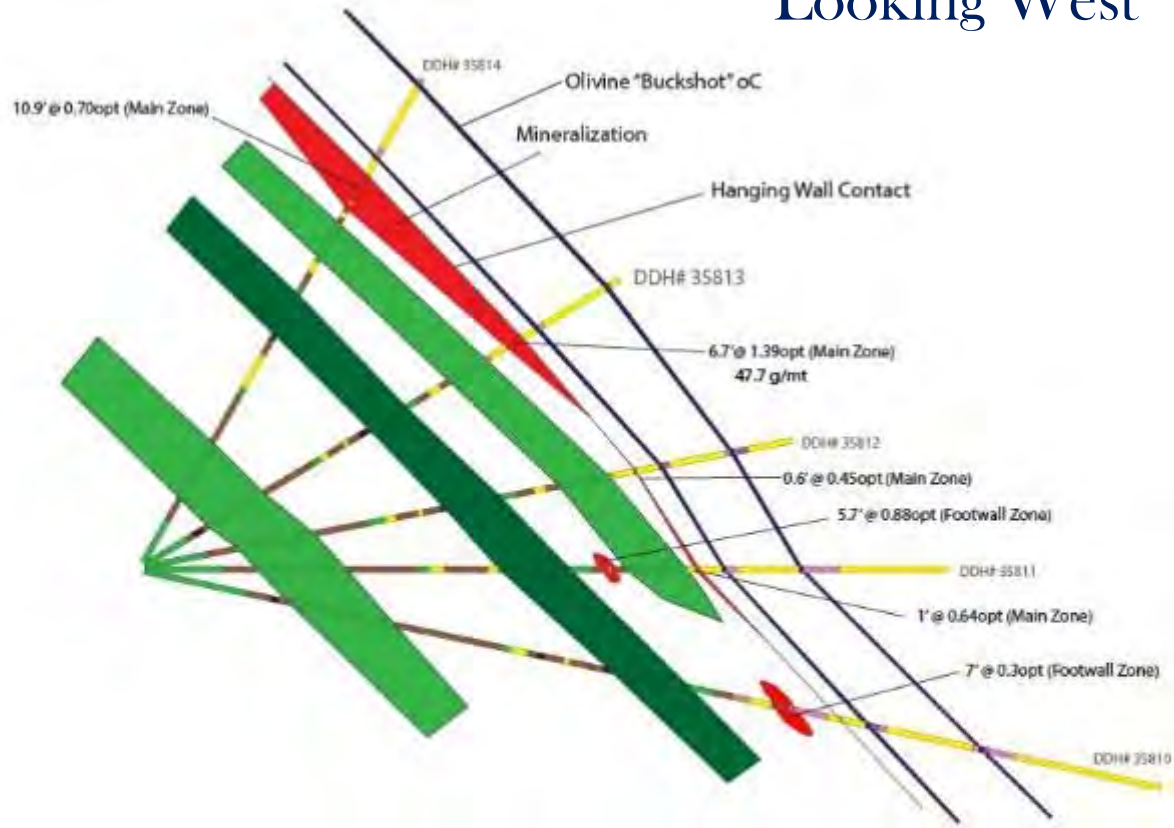
J-M Reef












4400 West 14,850 Diamond Drill Section

Looking West



Rock Types

- | | |
|---|---|
|  Gabbronorite - pbaC |  Anorthosite - pC, pCP, pC oiks |
|  Melanocratic Gabbronorite - MpbaC |  Leucocratic Troctolite - lpoCP, lpoC, lpoC oiks |
|  Leucocratic Norite - lpbC |  Troctolite - poC, poCP |
|  Norite - pbC |  Dunite - oC, oCP |
|  Melanocratic Norite - MpbC |  Mineralization |
| Hanging Wall Contact | |

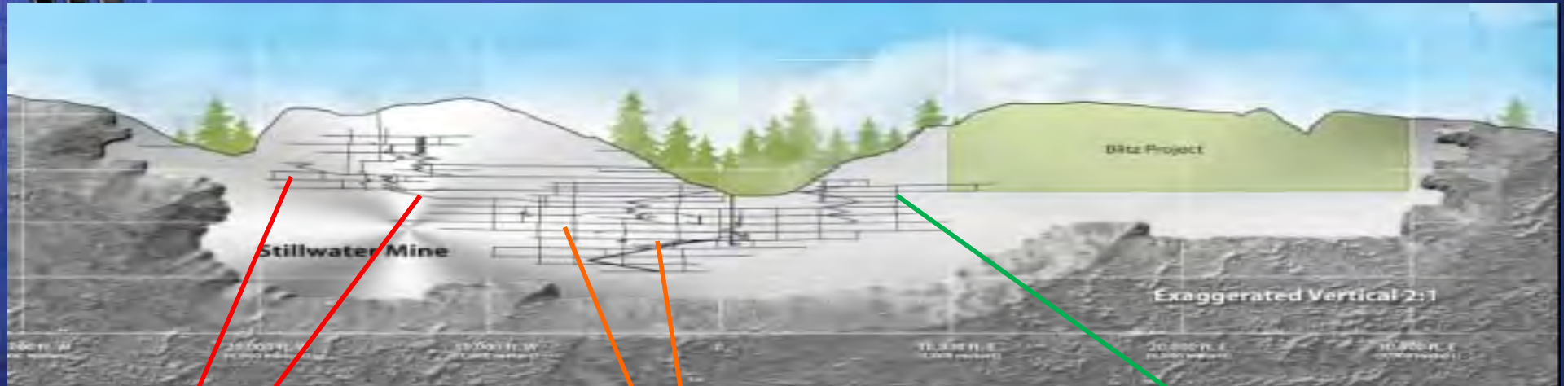
Minerals/Symbols

- a = clinopyroxene - augite
- b = orthopyroxene - bronzite
- p = plagioclase feldspar
- o = olivine
- C = cumulate texture
- oiks = oikocystic texture
- P = pegmatoidal texture

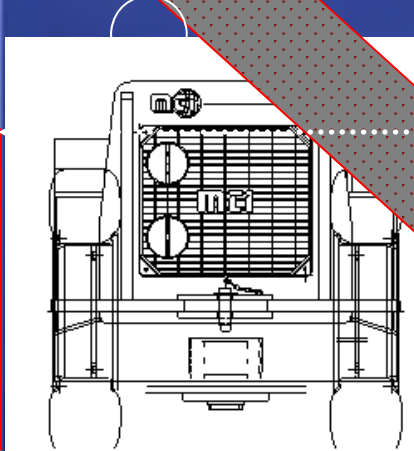
Narrow Vein Mining Methods



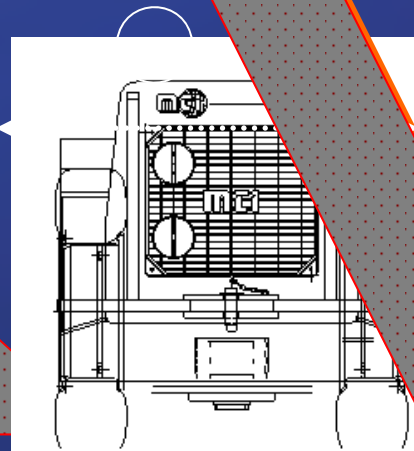
Longsection View & Related Mining Widths



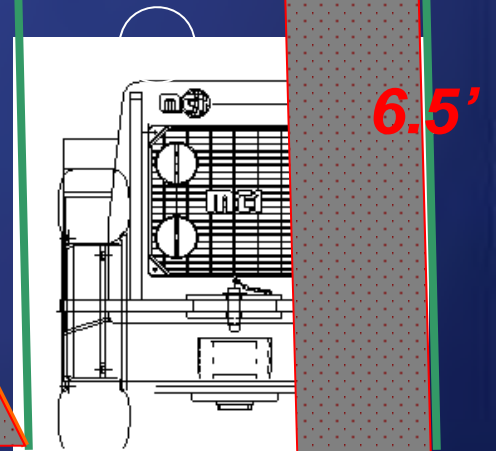
*~45 Degree
Dipping Contact*



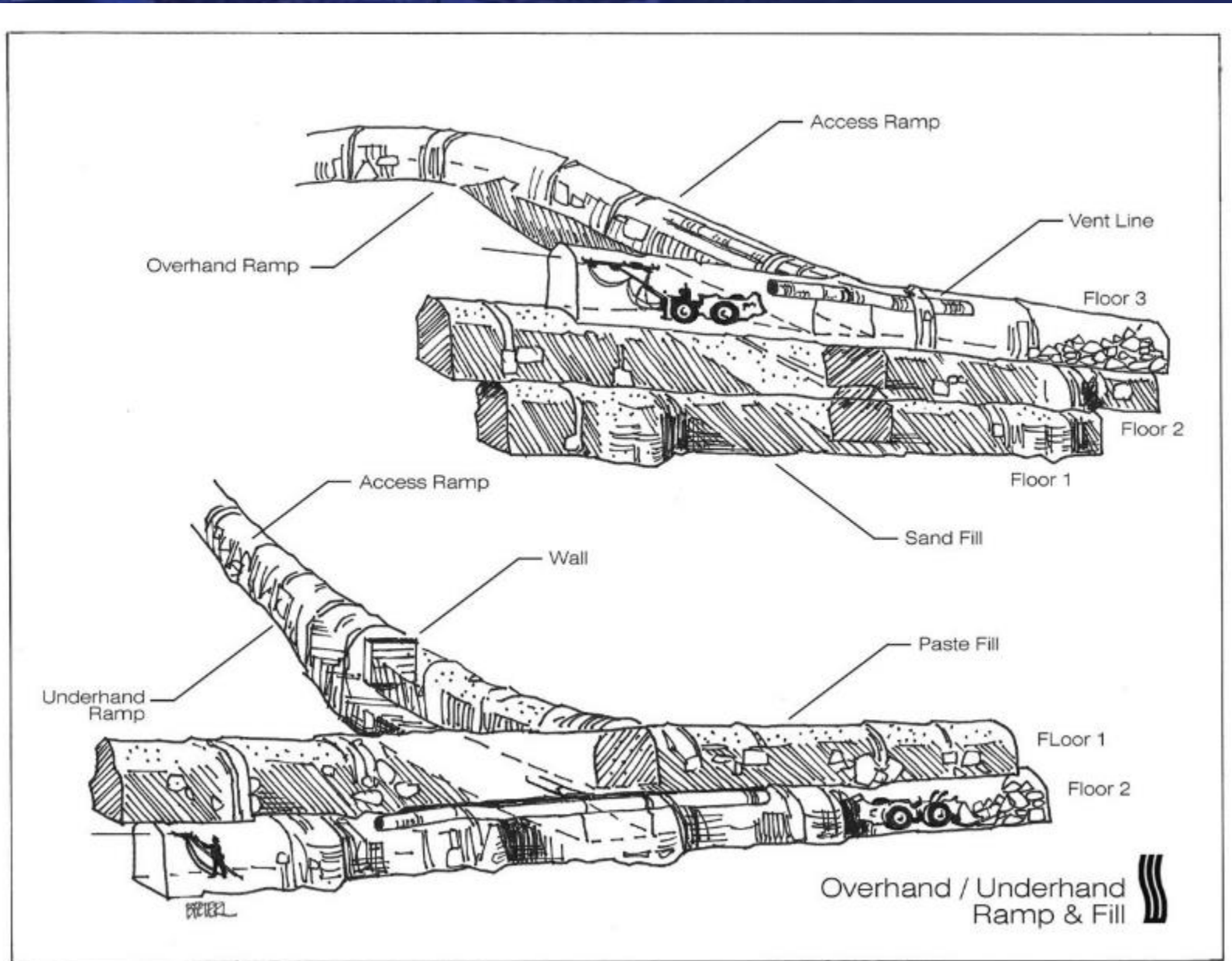
*~60 Degree
Dipping Contact*



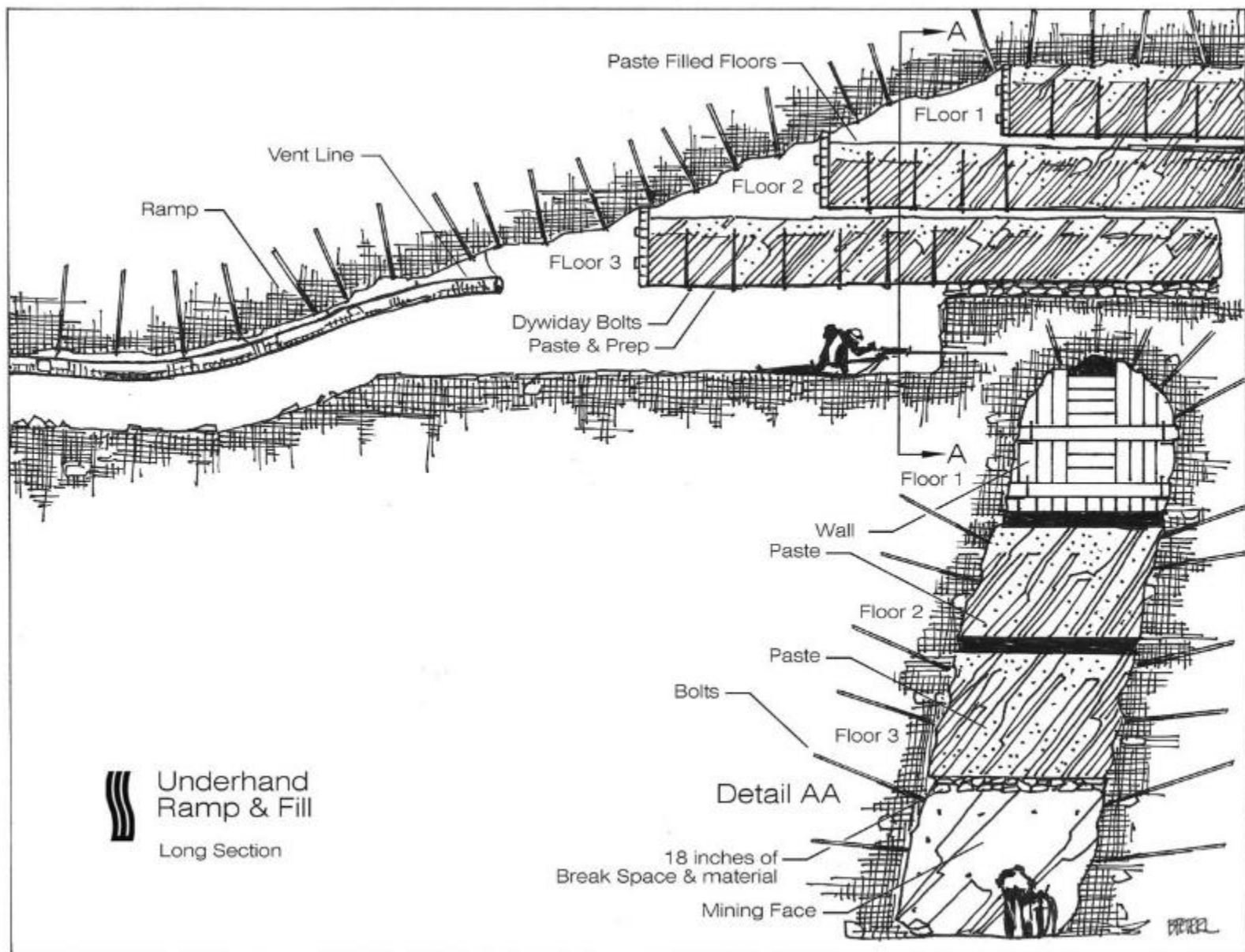
*~90 Degree
Dipping Contact*



Ramp and Fill: Overhand & Underhand



Underhand Ramp and Fill: cross section



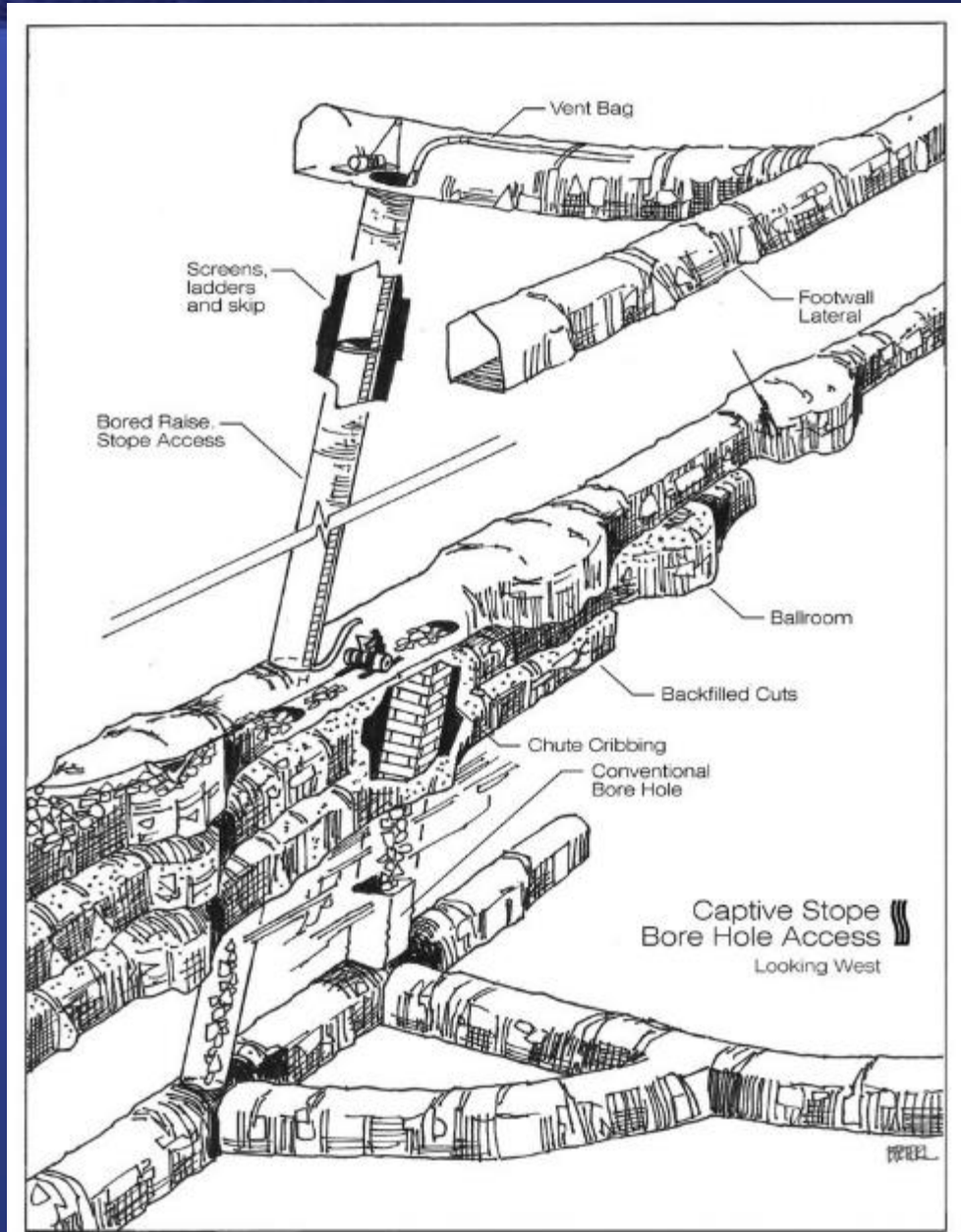


Jumbo Single Boom Drill

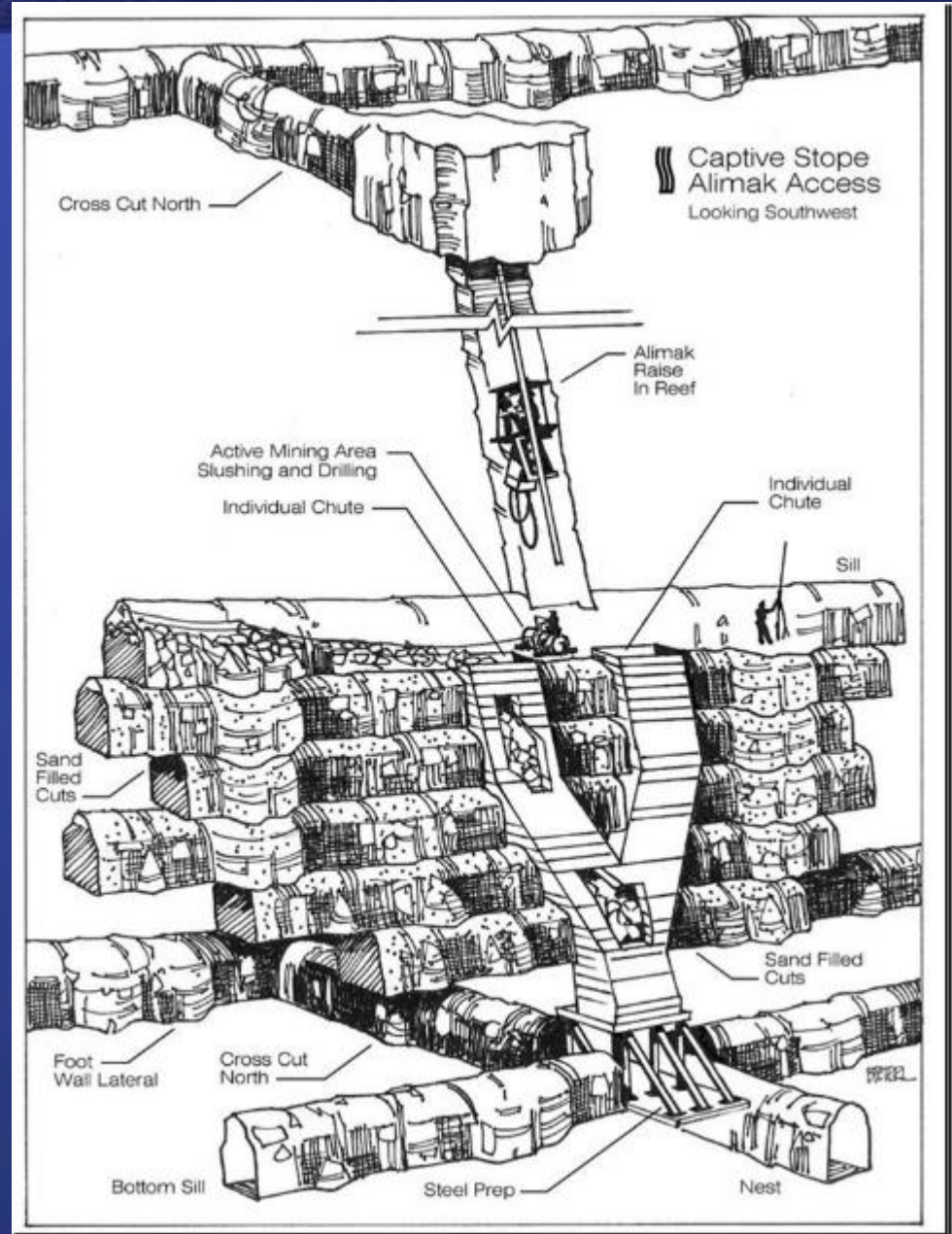
For ramp and fill & access tunnels



Captive Stope – Ladder Access

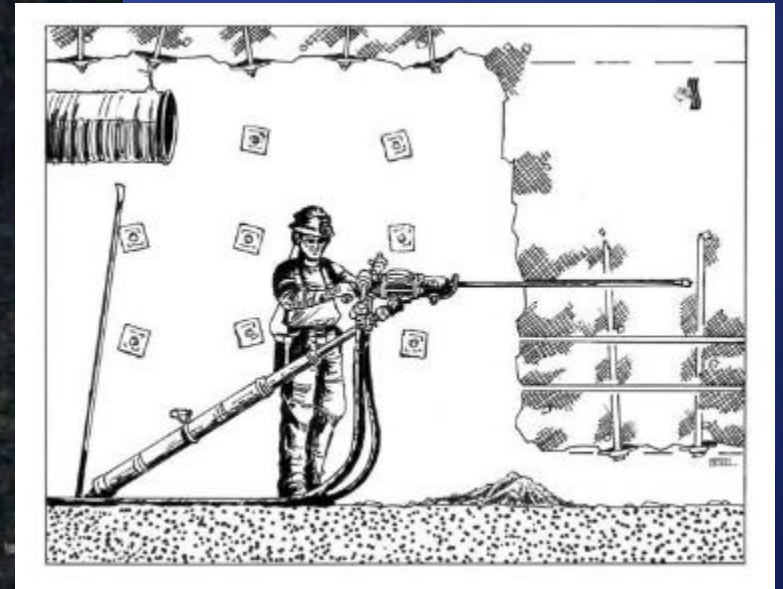


Captive Stope – Alimak Access

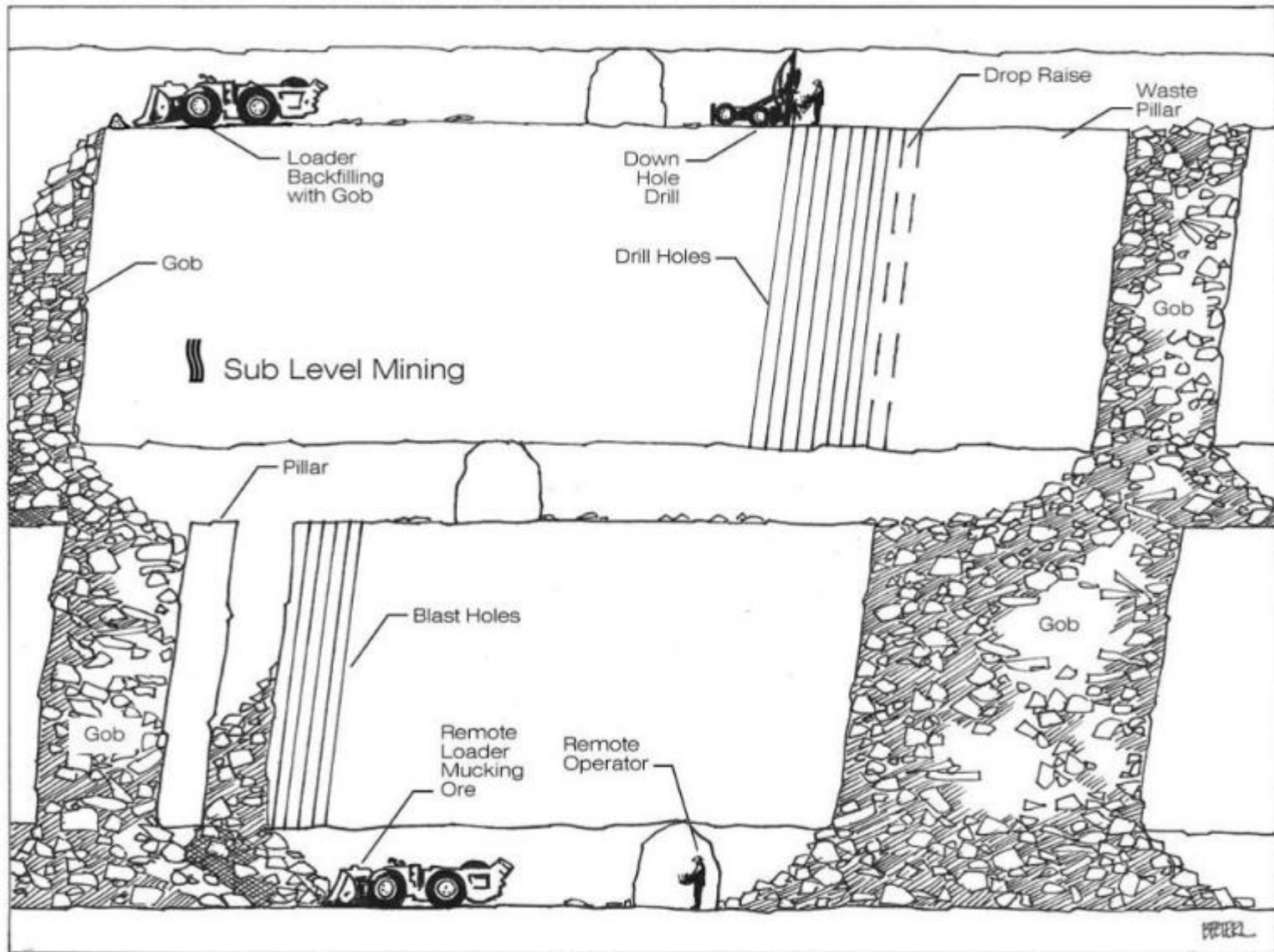




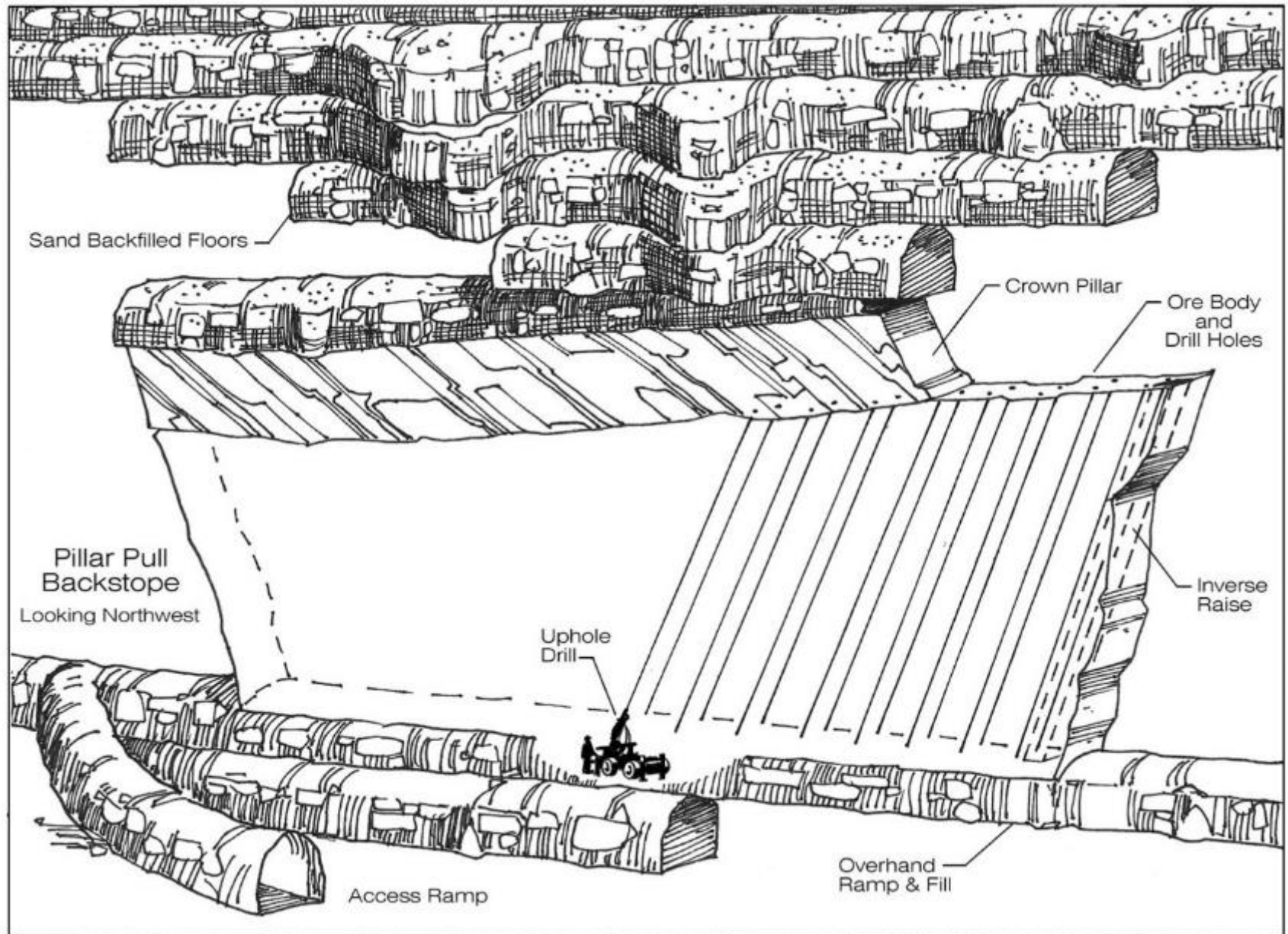
Jackleg: For drilling narrow headings & bolting



Sub-level Mining

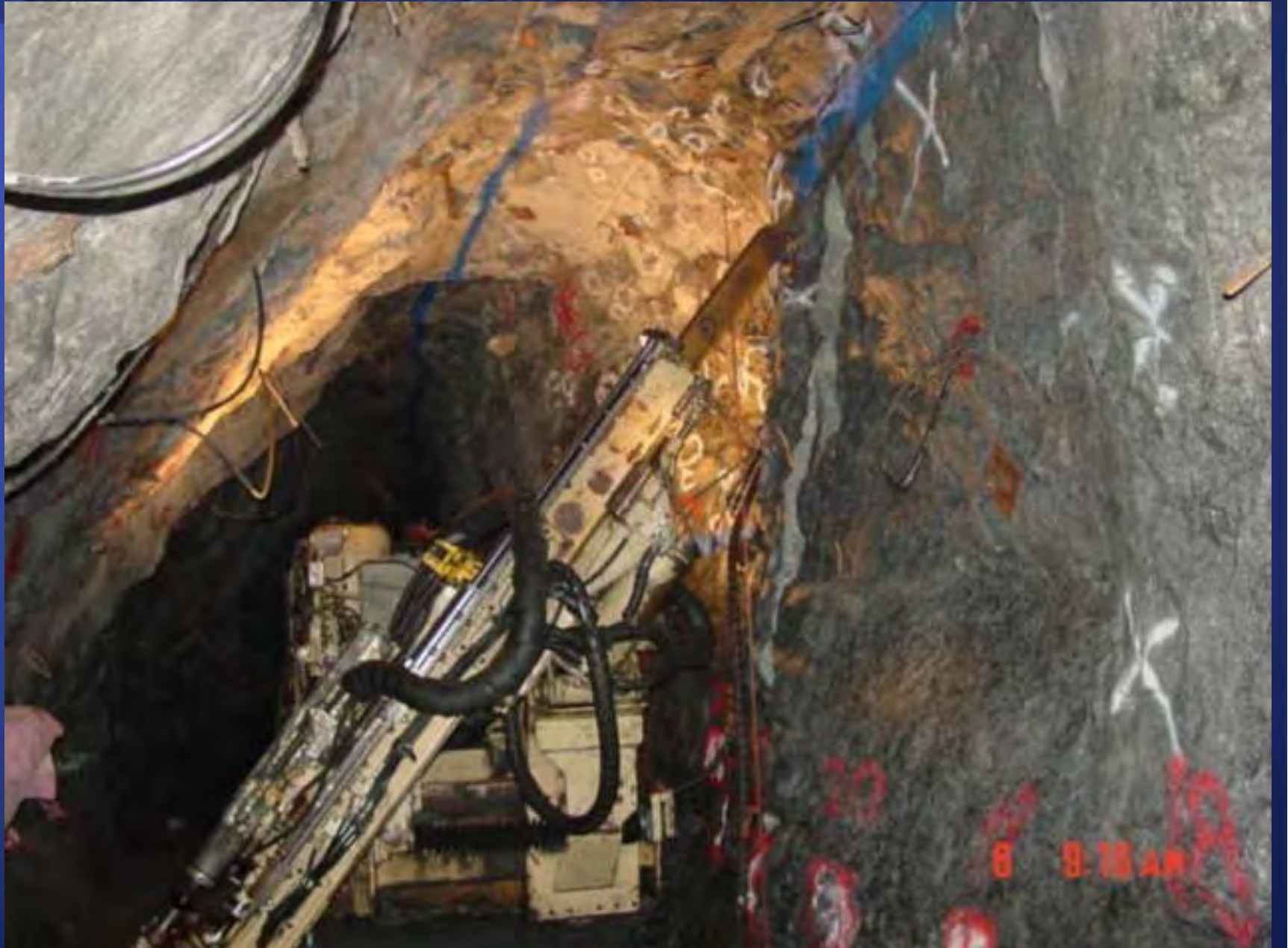


Sub-level - Pillar Extraction





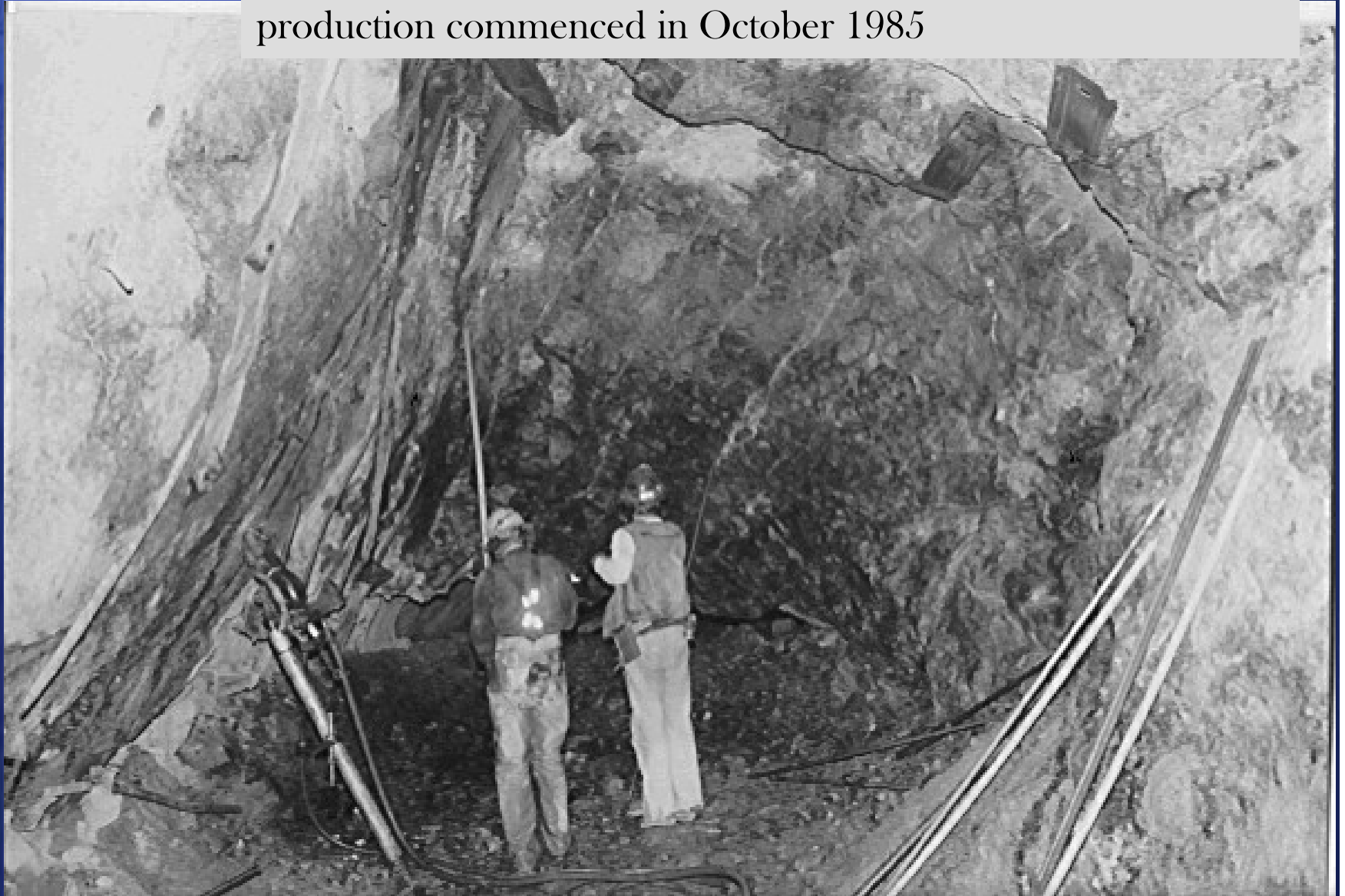
Sub-level Longhole Drilling





Geologic Grade-Control

SMC has utilized geologic grade-control since continuous production commenced in October 1985





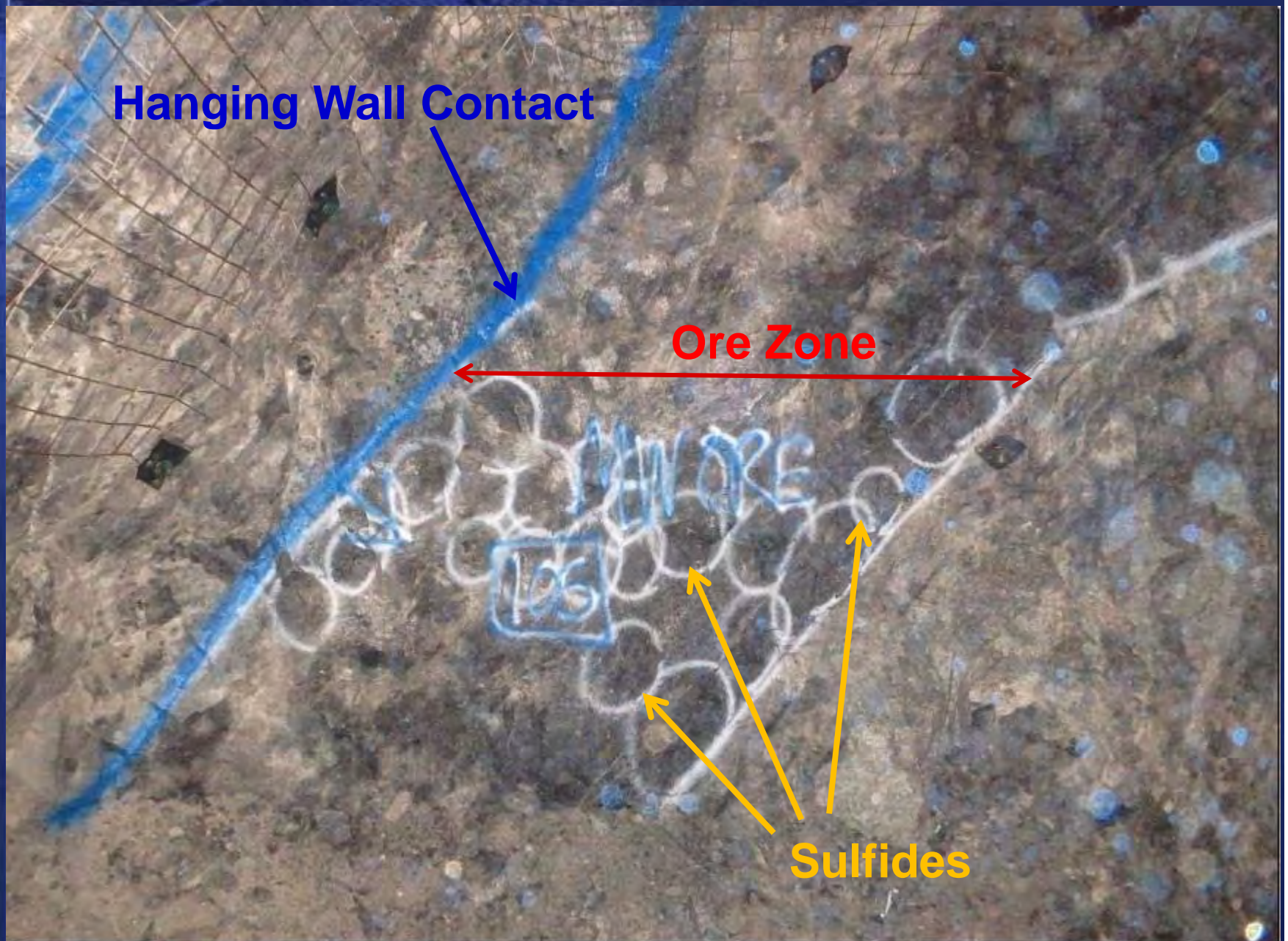
Geology Grade-Control Mark up



- ◆ Keep mining on reef and in ore
- ◆ Maximize ounce production
- ◆ Minimize dilution & deletion
- ◆ Advise production & engineering on stope planning and geologic issues
- ◆ Communicate with the production department to ensure accurate muck handling
- ◆ Increase Proven Reserve
- ◆ Provide ore width information for contracts

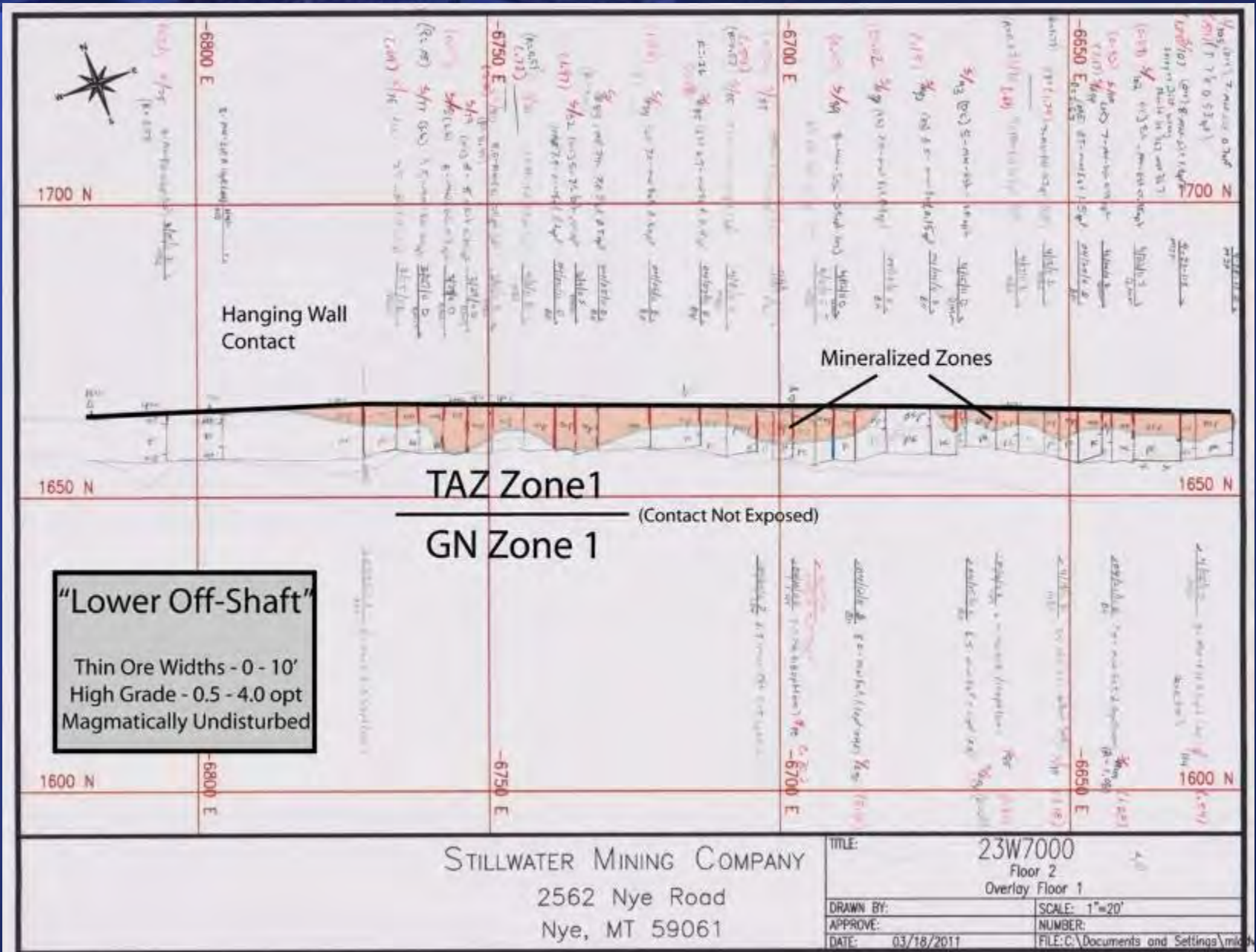


Geology Markup: 41W14,500 A3 east



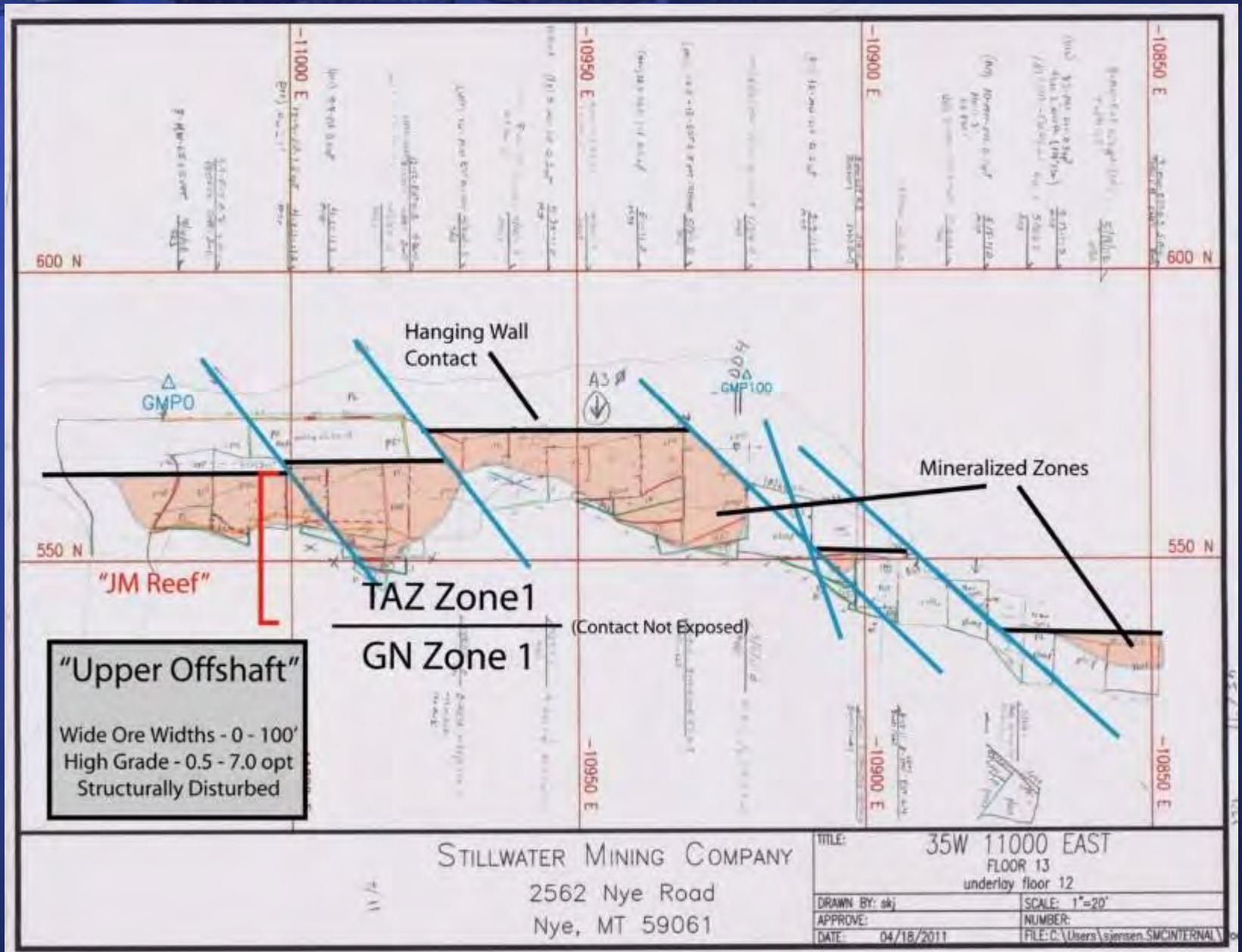


Lower Off-Shaft: 23W7000



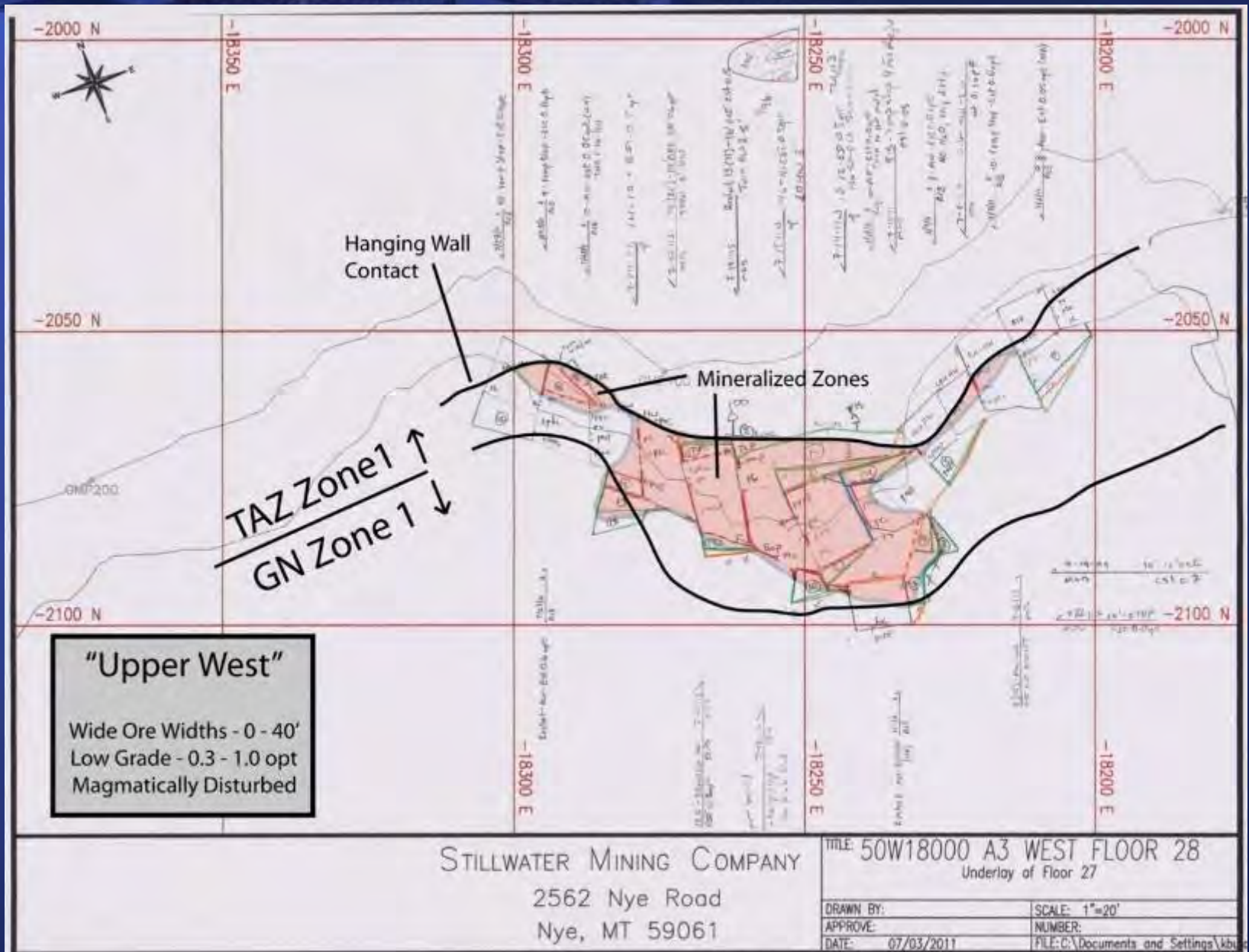


Upper Offshaft: 35W11000

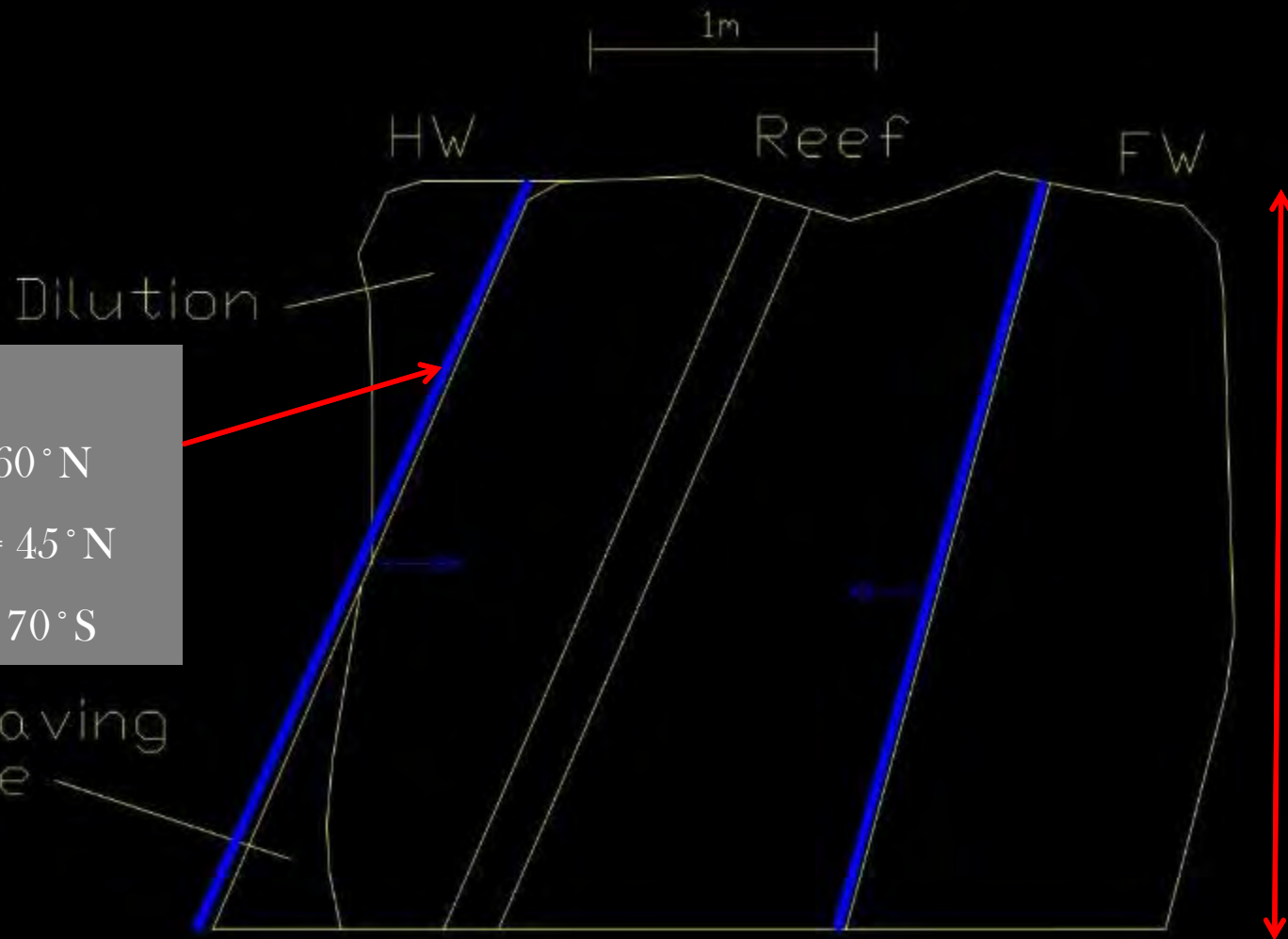




Upper West: 50W18000A3



Dilution and Deletion at the Face



Dip

Offshaft = 60° N

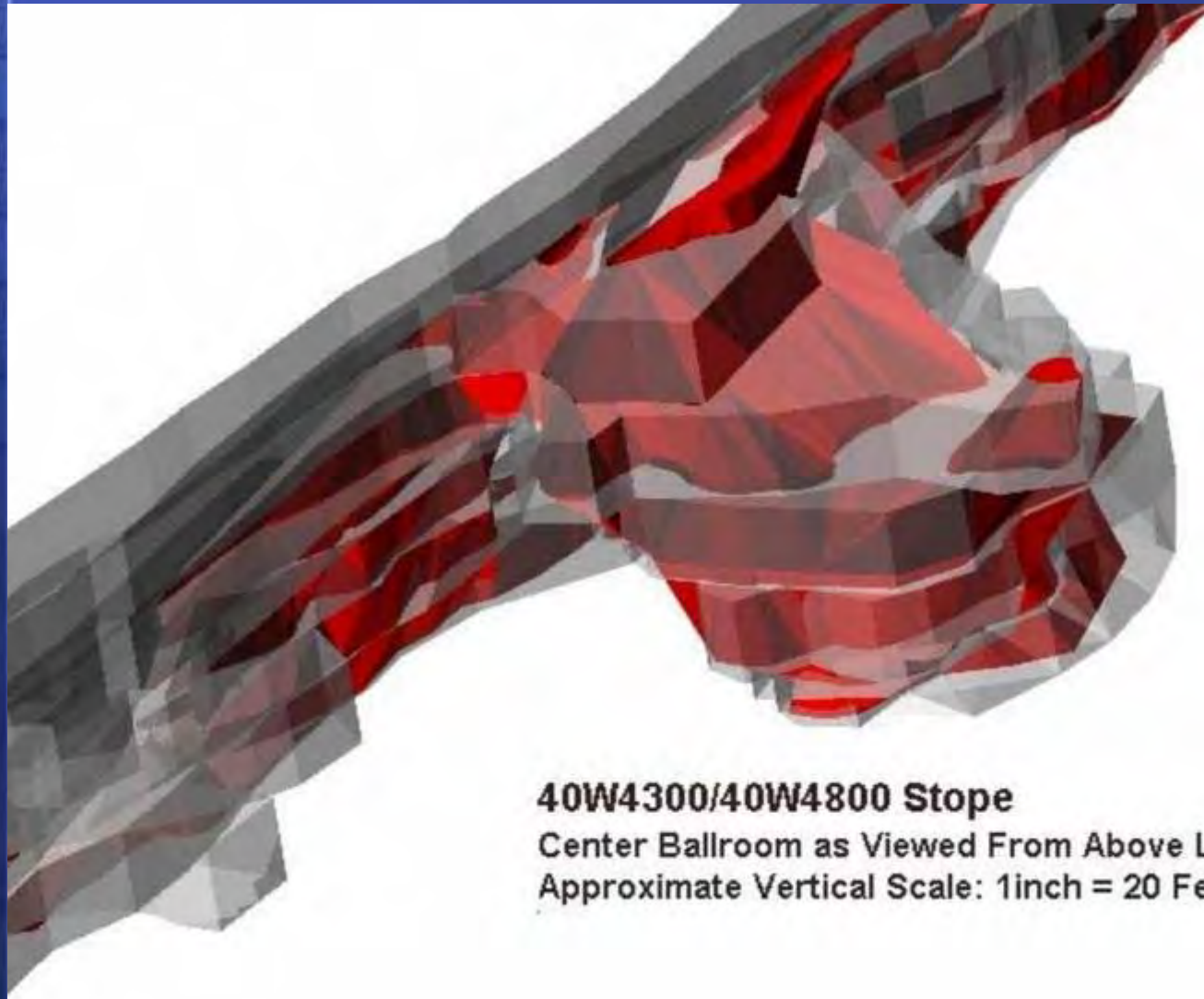
Upperwest = 45° N

East Side = 70° S

Leaving
Ore

Cuts are ~ 10' High

Ballrooms



40W4300/40W4800 Stope

Center Ballroom as Viewed From Above Looking Northeast
Approximate Vertical Scale: 1inch = 20 Feet

From 1 Ton of Ore:
40 lb (2%) is concentrated, producing ½ ounce of PGM



1 TON OF ORE
mined and sent to the
mill



3 GALLONS OF CONCENTRATE
sent to process

= ½ OUNCE of PGM
(½ of this coin)

