DEVELOPMENT OF A 3-D STRUCTURAL GEOLOGY MODEL OF HOMESTAKE'S 4100 TO 5000 LEVELS AT THE PROPOSED LOCATION OF THE LARGE CAVITIES

SDSMT CONTRACT #09-05

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To:

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k. 62 PIL Line
l. 63 STP Line
m. 65 PIL Line
n. 66 STP Line
o. 68 STP Line

NOTE: PIL, STP, HLME, ETC. shown on the geologic maps and sections are terminology used on former mine grid.

(Lisenbee-Terry 5/21/09)

I. INTRODUCTION

I.1 Purpose

In the spring of 2009 the Large Cavity Advisory Board (LCAB) recommended the preparation of two sets of information prior to their site visit to the DUSEL facility (Homestake mine) at Lead, SD during the period July 6-10, 2009. These are:

1. *Develop a 3-D model of the structural geology between the 4100 and 4850 levels.*
2. *Prepare a preliminary engineering geology assessment (including hydrology), drift conditions, and the potential cavity locations using the structural geology information (the 3-D model) as a base map.*

This report provides the first of these sets of information – that regarding a geologic model. The contract for the work specifically directs the preparation of "Cross sections and plans of the geologic features [that] identify:

a) The main rock types
b) The location of any shear zones or fault zones, particularly those that have infillings
c) Description of the contacts (welded, intact, sheared, etc.) between the rhyolite dikes [and the] host rock
d) Descriptions of foliation and/or any cross-cutting features
e) Description of the main joint sets"

I.2 Area of study

This study examines the geology between the 4100 and 5000 Levels (depth below the Yates shaft collar) in the area generally located between, and northwest of, the Yates and Ross shafts (Fig. 1.1). The area is identified as of interest for citing Large Cavities.

The wedge-shaped area extends approximately 2,900 feet north to south and a maximum of 2,000 feet in the east-west direction. This comprises an area of 4.36 million square feet (0.4 million square meters) and a volume of 3.9 x 10^9 cubic feet (110x10^6 cubic meters) (figures as quoted in contract). Drifts connect the Ross and Yates shafts in the eastern and south portions of the area.

I.3 Methods

The procedure used to construct the structural geology model was:

1) Examine existing maps, drill logs, cores, and the VULCAN data base at the SDSTA archives;

2) Briefly examine the accessible underground workings in the Homestake mine (4100 level) and the two cores drilled within the area;

3) Prepare a structure contour map on the top of the Yates unit, as well as 16 cross sections and 5 level maps for the area;

4) Prepare a preliminary 3-D model based upon the maps and sections;

5) Write the final report summarizing the findings of the work.

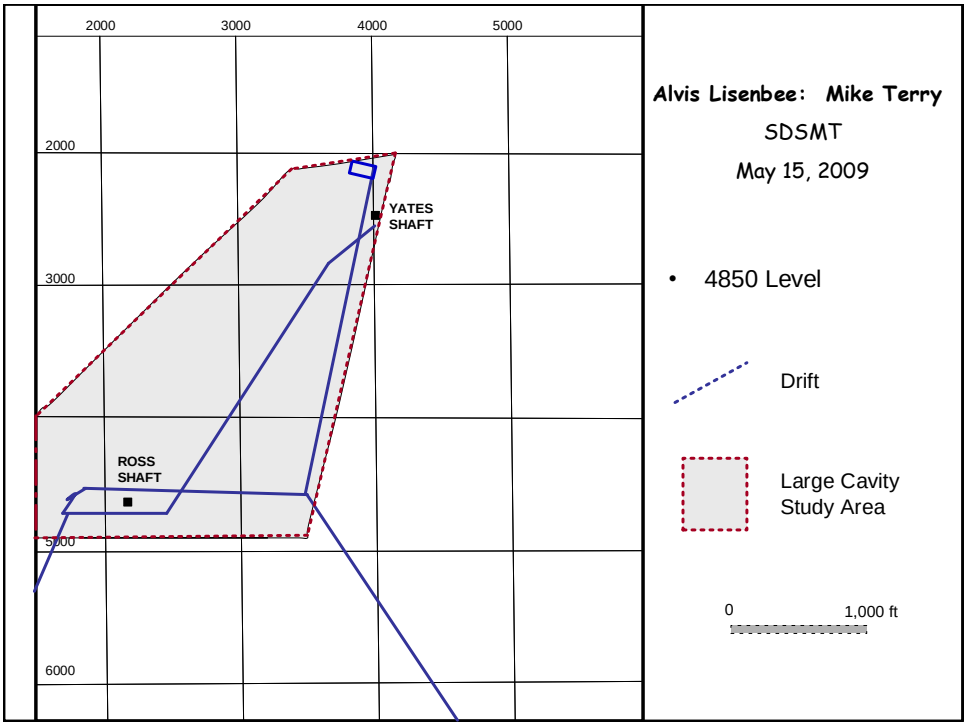

Figure I.1. Area for proposed Large Cavities, showing drifts on the 4850 Level.

I.4 Data used

This report is based in large part upon geologic information prepared by the mine geology staff and the exploration geology staff of Homestake Mining Co. over a period of many 10's of years. In that effort it is likely that many different geologists, having differing skills and agendas, participated. None of the area is in the former ore zone, for example, and less time may have been given to map preparation here (although some portions show remarkable detail) than in other areas of the mine.

The information used includes:

a) Level maps illustrating the geology to varying degrees of precision (1" = 50' and 1" = 100'). These are available for approximately 11,000 feet of drifts on the 4100 and 4850 levels within the area of study. In addition, for the area between the Yates and Ross shafts the maps show interpretations of the contacts between:
   i. The Yates unit (PCy) and the overlying Poorman Formation (PCp) (3950, 4100, 4850, 6800 Levels);
   ii. The "Homestake Formation" (PCh-2) contained within the Poorman formation (4100 Level in this area;
   iii. Tertiary rhyolite dikes that have intruded these formations (Tr) and;
   iv. Small areas of Homestake Formation (PCh) and Ellison Formation (PCe).

b) Drill logs for 1140 feet of core in amphibolite at the 4850 (DH#11537 and DH#11533).

In addition to a review of the existing Homestake data, the authors:

1) Examined core from the two exploration drill holes;

2) Examined aspects of the Yates unit (amphibolite) and Poorman Formation along a drift of 4100 level near the Yates shaft (participants included Dr. Mike Terry, Dr. Bill Roggenthen, Dr. Zbigniev Hladysz, and Mr. Tom Trancynger). The group inspected areas of the Yates unit (amphibolite) as well as the Poorman Formation/Yates unit contact near to the Yates shaft.
{{Inspection of the 4850 level was not possible due to flooding}}

3) Undertook several discussions with Ms Kathy Hart and Mr. Tom Trancynger regarding their knowledge of the study area based upon their experiences working as mine geologists there.

I.5 Personnel

Dr. Alvis L. Lisenbee and Dr. Mike Terry of the Department of Geology and Geological Engineering at the South Dakota School of Mines and Technology prepared the geologic model discussed here. Assistance given them by Ms Kathy Hart (maps and sections generated in VULCAN), Mr. Tom Trancynger (discussions relating to the geology and guidance during the underground visit), and Dr. Jaret Heise were essential components of this study.

I.6 Duration of study

The study was undertaken during the period March 1 through May 15, 2009.

II. GEOLOGY

II.1. ROCK UNITS

A preliminary examination was carried out between the Yates and the Ross shafts on the 4100 level, focusing mainly on the Yates unit. These observations are supplemented by descriptions posted on the geologic maps of the 4100 and 4850 levels.

Yates unit (amphibolite) (PCy on geologic maps and sections)

Just north of the Yates shaft, the Yates unit is predominantly fine-grained amphibolite schist crosscut by Tertiary age rhyolite. The amphibolite has a strong compositional layering which may in part be due to changes in grain size (Campbell 2008) and variations in proportions of plagioclase and hornblende. Locally, there are interlayers of sericite-biotite phyllite on the order of 10-25 cm in thickness. This layering is interpreted as bedding in an original volcanic pile which was later transposed during deformation (Fig. II.5A). This layering strikes NNE to N-S and dips ESE or E at 30° to 45°. The compositional layering is parallel to schistosity in both the amphibolite and phyllite layers. In addition to phyllite, there are what appear to be originally sulfide rich layers that are oxidized and appear to significantly weaken the adjacent rock. These may have been sulfide facies iron formation (Campbell 2008) or layer parallel sulfide rich veins (Fig. II.5B, C).

The amphibolite is also locally crosscut by numerous calcite veins with alteration selvages (Fig. II.5D). These selvages are interpreted to result from chloritization of amphibole and possibly the introduction of calcite and/or ankerite (no thin sections available). These calcite veins or in some cases veinlets (Fig. II.5D) are common in the Yates unit and locally cause significant weakening of the rock (Zbigniew Hladysz, personal communication). These are identical to calcite veinlets seen in the drill core examined during this project. Thin veins to large masses of “bull” quartz are also present

Poorman Formation (PCp on geologic maps and sections)

On the 4100 level south of the Yates shaft the Poorman Formation is typically a graphitic sericite-biotite phyllite that locally contains interlayered quartz. On geologic maps for the 4100 and 4850 drifts the unit is described as both phyllite and schist. It is a distinctive rock having “bands” one to five centimeters thick of probable original bedding. It is commonly folded from the scale of crenulations to that of larger mesoscopic folds (Fig. II.5H). The beds may contain coarse-grained biotite, with or without garnet, and varying portions of pyrrhotite. Massive quartz bands with pyrrhotite are common.

Homestake Formation (PCh-2 on geologic maps and sections)

Limited exposures in drifts on the 4100 level reveal a rock similar in composition to the Homestake Formation which overlies the Poorman throughout the district. The rock is readily recognizable due to the presence of a distinctive mineralogy. This includes the

amphibole cummingtonite and elongated masses of quartz. The carbonate mineral ankerite may also be present as well as abundant pyrrhotite, arsenopyrite, and chlorite.

The presence of this unit located within the Poorman Formation is a subject of controversy. In one scenario the unit, which is similar to the overlying gold-bearing Homestake, was deposited under similar conditions as that formation, but at an earlier time. Alternatively, it may be Homestake Formation enfolded as an isoclinal, recumbent syncline into the Poorman.

Tertiary Rhyolite Dikes (Tr on geologic maps and sections)

Rhyolite porphyry dikes were examined in the area of the Yates shaft and locally within the Poorman Formation. The dikes are aphanitic, but may contain phenocrysts of sanidine. Near the margins they are extremely fine-grained and commonly show "layering" parallel to the contact indicative of flow along a chilling margin or a gradational chilled border. Sulfide mineralization and alteration is locally present and may affect the rheologic properties of dikes. This mineralization is commonly associated with open-spaced fracture. Mineral present include pyrite, galena, sphalerite, molybdenite, fluorite, calcite and gypsum. In addition, this mineralization is associated with brecciation that is typically well annealed. These observations are similar to those made in drill core from the 4850 Level.

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II.2 STRUCTURAL FEATURES

A. Lead anticline

The Yates shaft penetrates the Yates unit (amphibolite) at approximately the 3775 level along the crest of the large, southeast-plunging (averaging~24°) Lead anticline (Fig. II.1). The area of this study extends from the crest of the fold across the western fold limb with dips of the contact, and of the schistosity within the unit, varying from ~20°SE along the crest to as much as 70°SW along the southwestern limb (Fig. II.2). The Ross shaft penetrates the Yates unit far down the southwest limb of the fold at approximately the 7,000 level.

The axial trace of the south-southeast-plunging Lead anticline lies 100-200 feet to the west of the Yates shaft. The Yates shaft and the Davis Cavern lie in the east limb of the fold at the 4100 level. Only a small portion of the study area lies to the east of the fold axis.

B. Yates unit (amphibolite)

Although the Yates unit (amphibolite) is a massive rock in many areas there are numerous heterogeneities. These include the contact zone with the phyllite of the overlying Poorman Formation, interlayers of phyllite and sulphide-rich rock within at least the upper portion of the rock mass, foliation/layering, fractures (commonly filled with calcite, gypsum, quartz, and/or pyrite), and contacts with numerous Tertiary rhyolite dikes.

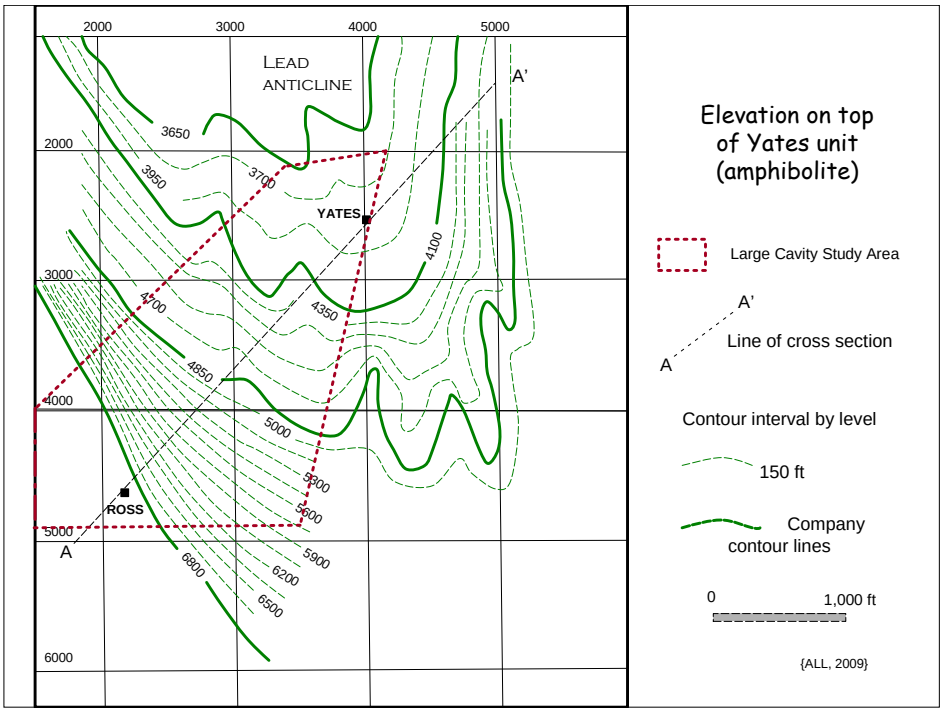


Figure II.1. Structure contour map on the top of the Precambrian Yates unit (amphibolite) in the area of the Yates and Ross shafts.

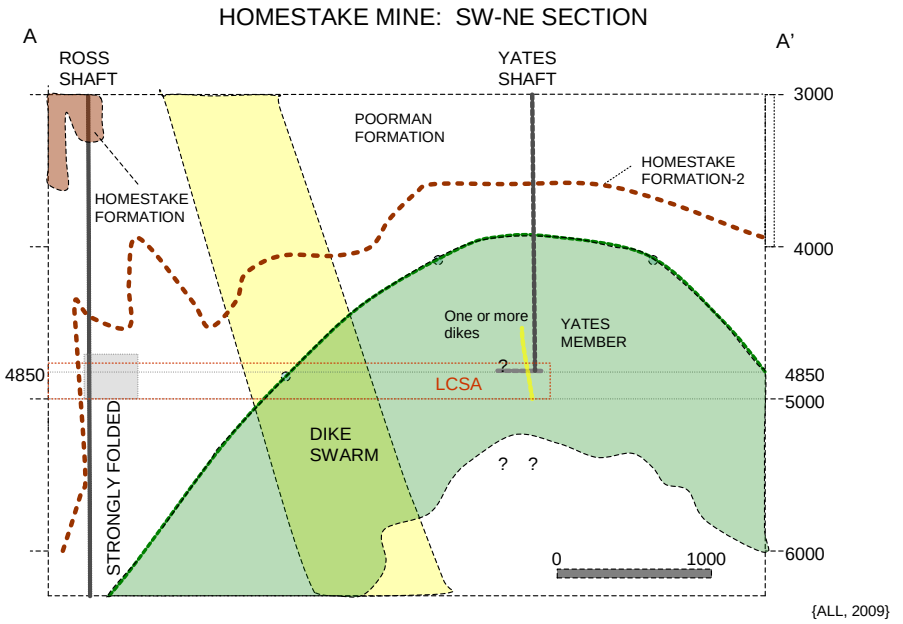


Figure II.2. Northeast-southwest cross section across the Lead anticline along a line including the Ross and Yates shafts. Numbers are depth below Yates shaft collar

1. Contact relationships

Yates unit/Poorman Formation

The upper contact of the Yates unit (amphibolite) is exposed in four drifts on the 4100 and 4850 levels. At the time of the study only the exposure south of the Yates shaft on the 4100 level could be examined. This contact is a zone of broken rock.

Yates unit/Tertiary rhyolite dikes

The contacts of amphibolite with rhyolite dikes seem to be annealed as seen in core and in exposures along the 4100 level. A thin (a few inches), fine-grained zone of recrystallization extends outward into the amphibolite and the margins of the dikes are extremely fine-grained (almost porcelain-like). The contact zone is undulatory at scales ranging from cms to the strike length of the dike.

2. Foliation/layering

The degree of foliation development within the Yates unit is quite variable although linear orientation of hornblende grains is near ubiquitous. Foliation (Fig. II.5A and B) is indistinct in some massive units and quite recognizable in others as parallel bands of contrasting color, grain size, or composition.

In the area west of the axis of the large Lead anticline, comprising approximately 75% of the study area, the schistosity/layering trends ~N.30°W: Dips to the southwest increase to as much as 70° within the area extending ~1,000 feet northeast of the Ross shaft, i.e., southwest of the 4850 structure contour line shown on the "Structure Contour Map on Top of Yates unit"

In the northeast corner of the study area (southwest of the Yates shaft on the 4850 level) foliation along the crestal portion of the SSE-plunging Lead anticline strikes east and dips approximately 35°S. In the east limb of the fold (4850 Geologic Map) foliation trends approximately N.20°E., and the dip increases from 17°E south of the Yates shaft to as much as 60°E in the area of Davis Cavern.

Anisotropy parallel to the foliation is enhanced by the presence of inliers of gray phyllite (altered in some cases to clay), sulphide bands (Fig. II.5B), quartz "streaks", and thin carbonate "veins". The phyllite varies in thickness from a few inches to several feet (as seen on the outcrop in exposures along Blacktail Gulch). The mineral bearing bands are generally thinner than six inches. There is insufficient information available at present to predict if such features are concentrated in various areas, if they are spread throughout, or if they are randomly distributed.

3. Shear zones/faults

No faults or shear zones are shown on the geologic maps of the drifts in this unit. One fracture in the amphibolite (N55^{o}W, 80°NE) near the Yates shaft on the 4100 level is noted as "water course" on the drift map.

4. Main joint sets

On the 4100 level near the Yates shaft the unit was observed to have a massive blocky appearance due to fractures. There are distinct sets of joints present in the unit (Fig II.5E). These include NW-dipping joints with rough surfaces. Another N-S striking E-dipping joint set (Fig. II.5F) intersects the foliation which allows the release of large wedge shaped blocks (Fig. II.5G).

Thirty six orientations of joints taken from the "4100 Level Geologic Map" are shown on Figure II.8 (A-4). They suggest two strong trends (Table 1) of N15^{o}E, 35°SE (generally parallel to foliation: Fig. II.5F) and N80^{o}E, 69°NW similar to those observed during the field examination of this project. A weaker set trends NW and dips SW at moderate angles, of which the fractures shown in Figure II.5-E in the drift south of the Yates shaft may be examples. In this latter case, the intersection of fractures and schistosity produces blocks whose upper edges parallel the drift.

Many of these discontinuities are recognized as thin calcite veins (<1mm-2cm) (Fig. II.5-D). The lateral extent of the trends listed above is unknown, but similar calcite veins are abundant (many per meter) in the amphibolite cores examined from the 4850 level.

As seen in this photograph, there are selvages of lighter color extending outward into the country rock from the calcite veins, apparently indicating alteration of the amphibolite. Such alteration will add to variations in rock strength. Because they cross cut the rhyolite dikes as well, most of these veins and alteration zones are considered to be of Tertiary age.

Fracture trends (Table 1; Fig.II.8-BT1) measured in amphibolite outcrops along Bobtail Creek (approximately one mile to the north) do not parallel those near the Yates shaft (as shown on the geologic map of the drift) although the attitude of the upper Yates unit there is similar (N66^{o}E, 23°SE) to that at depth along the crest of the fold. Fractures

Figure II.3. Yates unit exposed along the Blacktail Gulch road. Foliation/layering is inclined to the right: Fracture sets dip to the left and parallel the exposure face. View to northeast.

divide the massive unit shown in Figure II.3 into blocks one to three feet on a side. In the 4100 drift near the Yates shaft fracture sets surround blocks a foot or less in dimension (Fig.II.5E, and G).

A relative comparison of the rock character may be inferred from the nature of breakage of the core. The segments are broken during both drilling and retrieval from the core barrel. As shown in Figure II.4, the amphibolite is broken into fewer fragments per two foot length (the length of the core box) than is the rhyolite. Some breakage occurs when the core is “fitted” to the box.

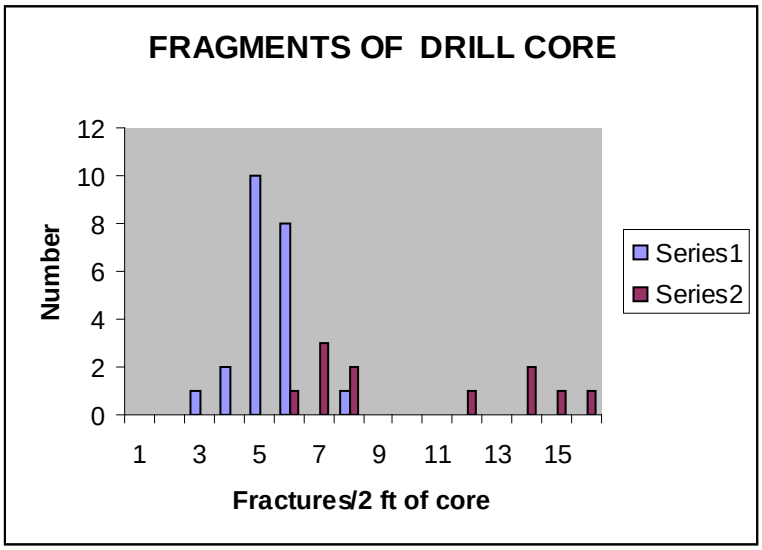


Figure II.4. Number of fragments of amphibolite (Series 1) and rhyolite (Series 2) per two foot of core length. The core boxes are archived at the core storage facility DUSEL site (Homestake Mine). Drill holes #11537 and #11533.

Figure II.5. Photographs on the following pages taken within the Yates unit (amphibolite) on the 4100 level. (M. Terry)

A) Facing eastward in the 4100 drift just immediately north of the Yates shaft. Photo shows characteristic layering/schistosity in the Yates unit.

B) Facing southwest: Yates unit with bright layers interpreted as oxidized sulfide layers of possible sulfide-facies iron formation.

C) Photo showing more detail of the NE corner of photo B.

D) Calcite veins with alteration selvages.

E) East wall of the 4100 drift showing the blocky character of the Yates unit. White lines show prominent fractures.

F) View of back facing south. West dipping joints (solid lines) intersecting southeast-dipping foliation (dashed).

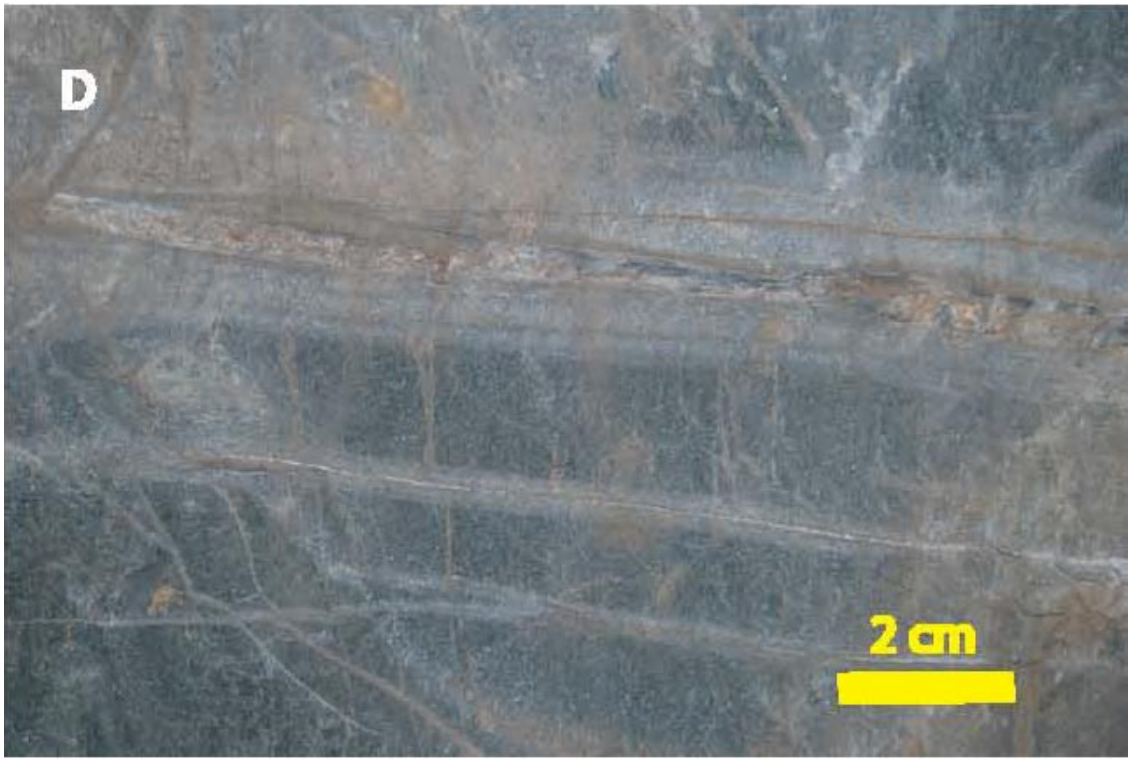
G) Fallen blocks released from intersecting weaknesses in Figure F.

H) Folding in Poorman. Dashed lines show axial traces of folds at the contact with the Yates unit.

A

B

C


D
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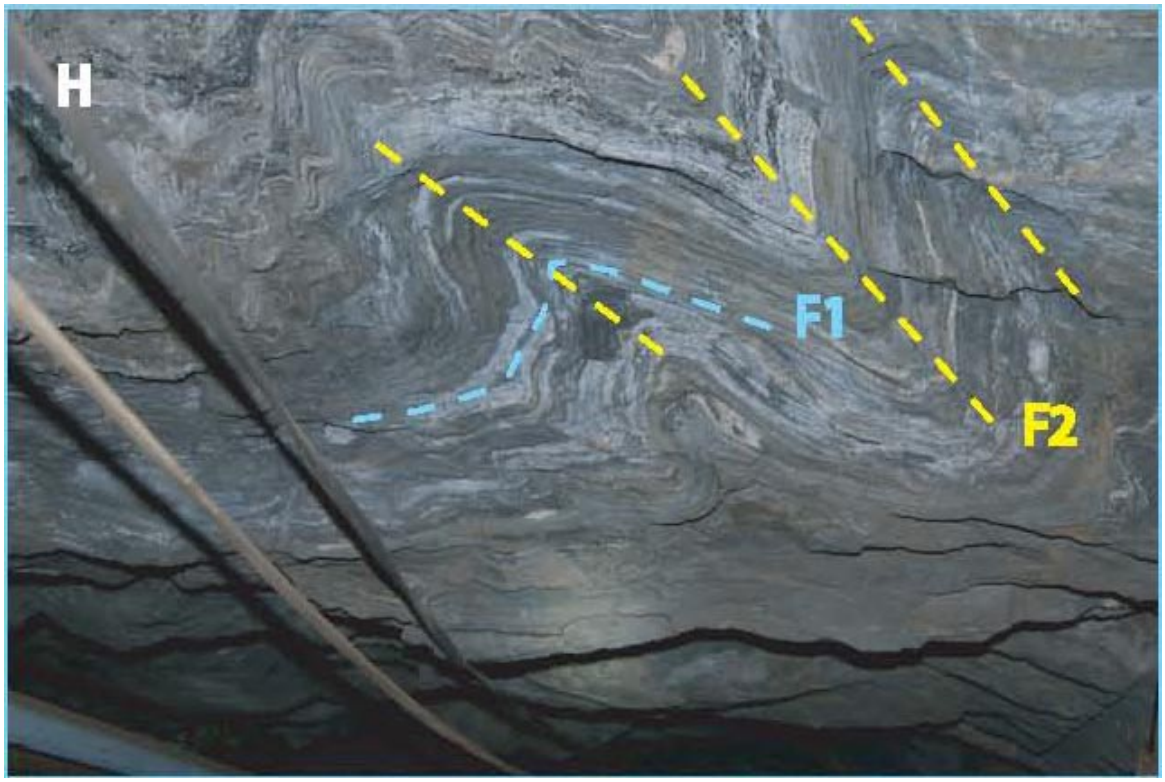
E

F

G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F1
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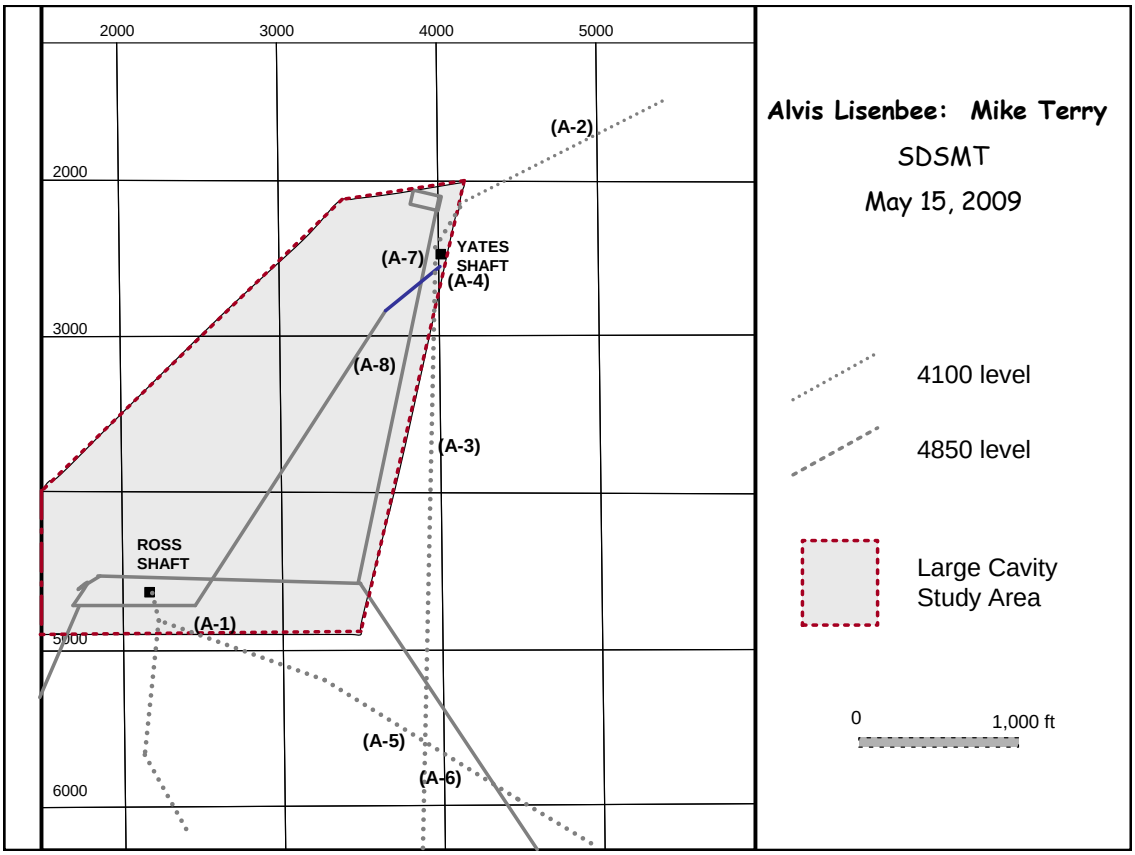


Figure II.6. Locations of stereonets shown Figures II.7, 8, and 9.

Table 1 Stereonet data: Locations and file numbers

Level	Location**	File numbers in Appendix A
4100	A1	2, 6, 12
4100	A2	4, 5
4100	A3	7
4100	A4	3
4100	A5	1
4100	A6	8
4850	A7	3, 9, 11
4850	A8	10

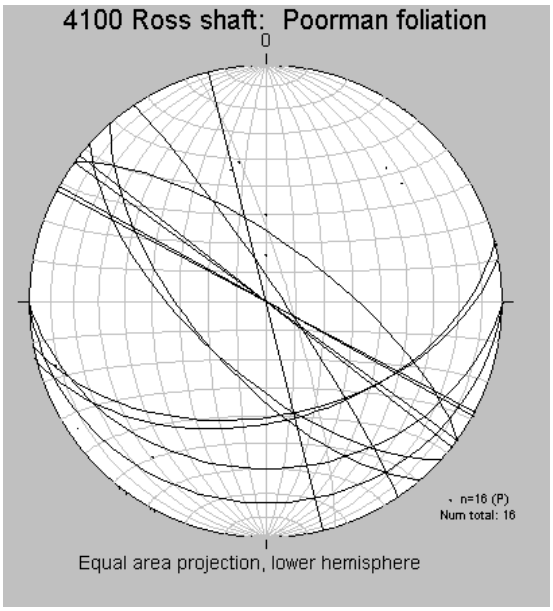
**See Figure II.6 for general locations.

Table 2. Stereonet results of fracture, foliation, and fold orientations on the 4100 and 4850 levels, Homestake mine in the Large Cavity Study Area (Yates and Ross shafts).

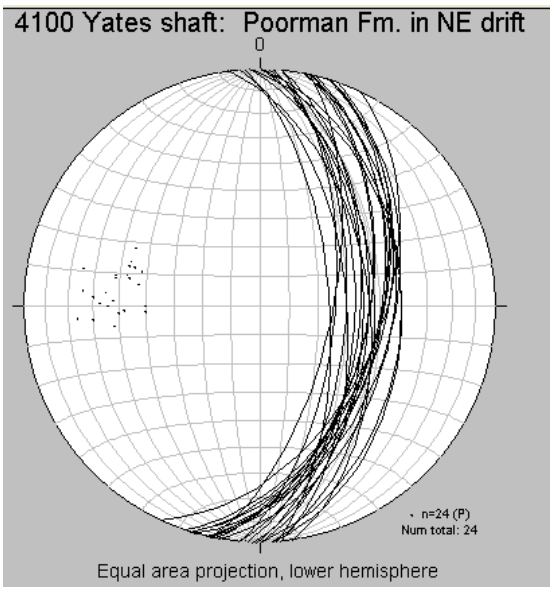
Location	Fracture 1	Fracture 2	Fracture 3
A-1}Ross Shaft--4100 0-600 SE (Poorman)	N68^{o}E, 90°	N30^{o}W, 90°	Random, shallow
A-2}Yates Shaft--4100 800-1200 ft NE (Poorman)	N17^{o}W, 62°W		
A-3}Yates Shaft—4100 Yates unit (amphibolite)	N15^{o}E, 35°SE	N80^{o}E, 69°NW	SW, NW dip
SURFACE: Blacktail Gulch Road	N2^o-25°W, 90°	N52^{o}E, 60°N	N66^{o}E, 23°SE (Foliation)

Location	Foliation/bedding	Fold plunge	
A-1}Ross shaft—4100 (Poorman)	N55^{o}W, 90°	N75^{o}E, 47°SE Fold plunge 18°, S58^{o}E Mesoscopic folds = 36°, S7^{o}E	
A-2}Yates shaft—4100 (NE drift-Poorman)	N9^{o}E, 48°SE	(parallel layering, only minor mesoscopic folding)	
A-3}Yates shaft--4100 (Poorman -S of Yates contact)	N85^{o}W, 35°SW		
A-4}Yates Shaft—4850 (amphibolite)	N20^{o}E, 50°SE	N70^{o}E, 35°SE Mesoscopic folds: plunge = 36°, S45^{o}E	N55^{o}W, 75°W
A-5} Yates shaft—4100 West from drift intersection	N10^{o}W, 42°NE +variable	Lead anticline plunge = 30°, S40^{o}E	
A-6}Yates shaft/S—4100 (Drift intersection)	N, 35°E	Lead anticline plunge = 30°, S40^{o}E Abundant mesoscopic folds	
A-7} Yates Shaft—4850 (amphibolite)	N52^{o}E, 32°SE	N11^{o}W, 78°SW Mesoscopic folds = 28°, S6^{o}E (Stereonet)	

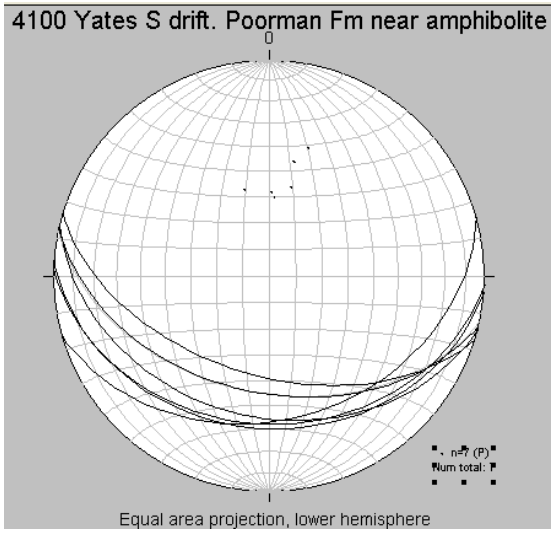
***See Appendix I for dip and strike data set.*



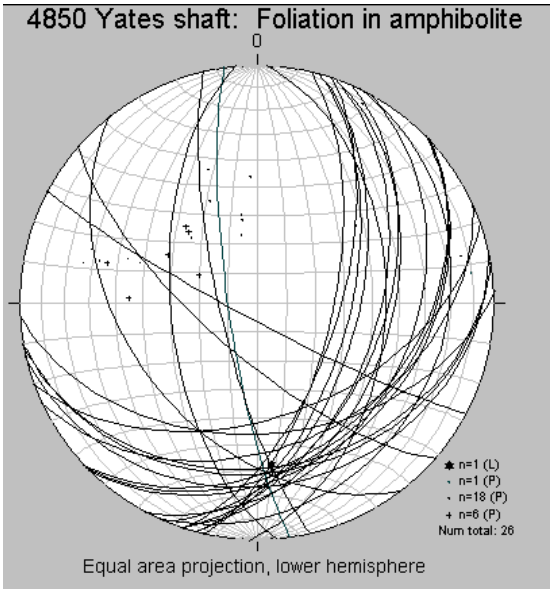
Location A-1. 4100 Ross shaft, Poorman Formation.



Location A-2. 4100 Yates shaft, Poorman Formation in NE drift.

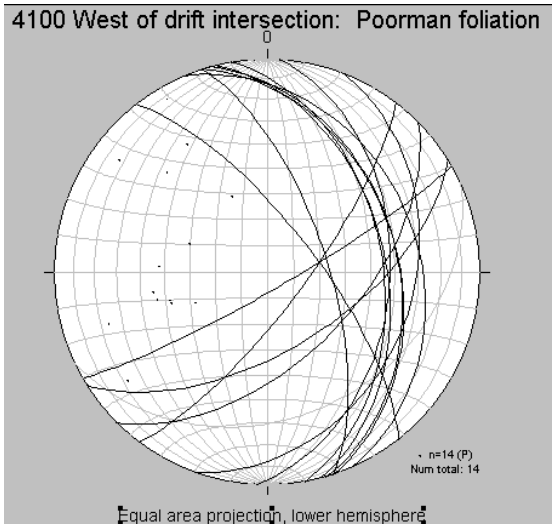


Location A-3 Yates shaft, Poorman Formation, south in drift.

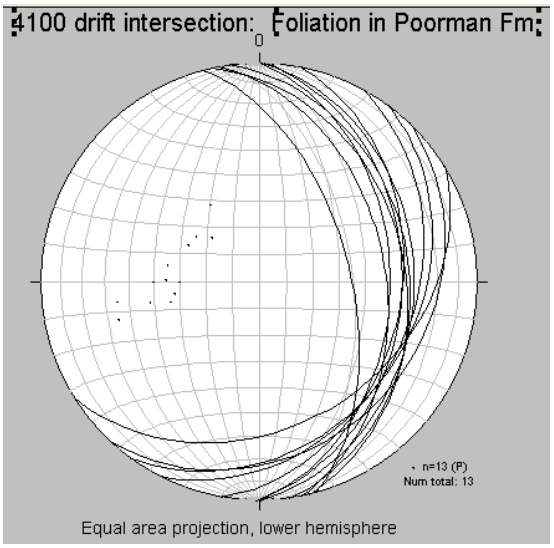


Location A-4. 4850 level, Yates shaft. Yates unit (amphibolite).

Figure II.7. Foliation/layering in the Poorman Formation and Yates unit (amphibolite).

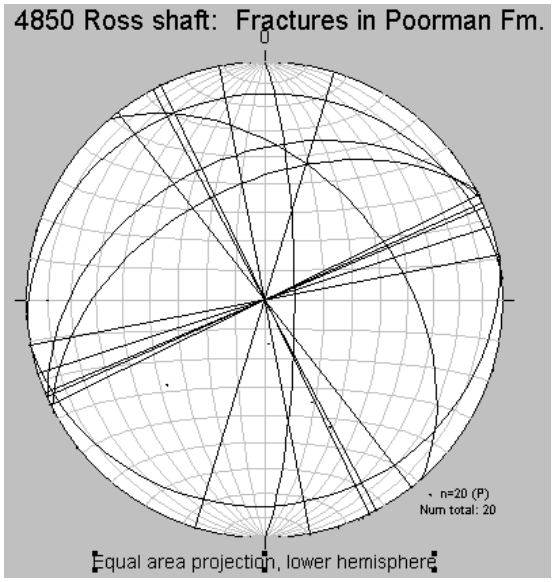


Location A-5. 4100 level west of drift intersection, Poorman Formation.

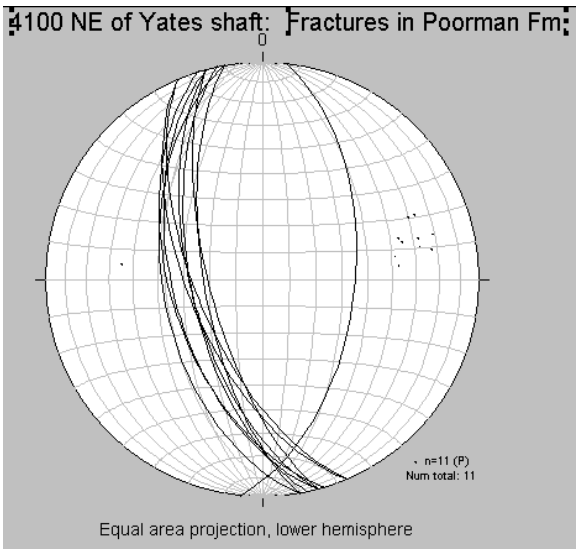


Location A-6. 4100 level, drift intersection, Poorman Formation.

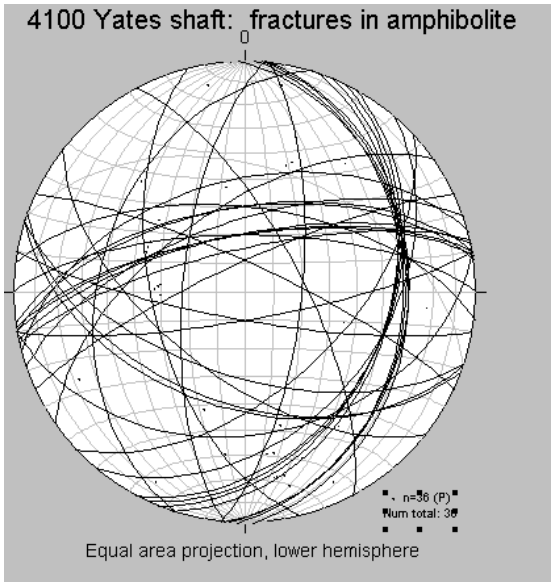
Figure II.7. Foliation/layering (continued).



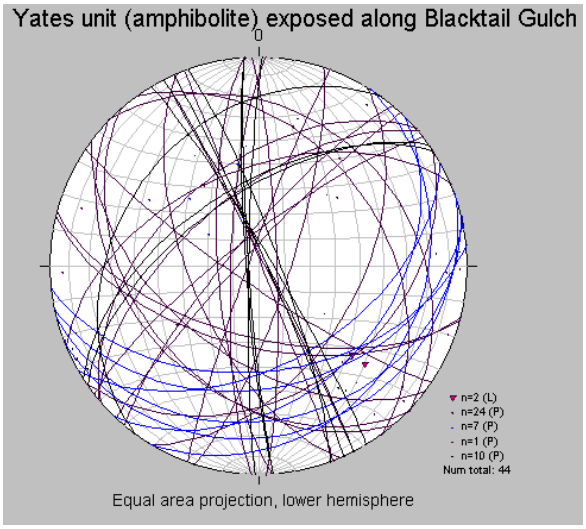
Location A-1. 4100 Ross shaft: Poorman Formation



Location A-2. 4100 level northeast of the Yates shaft: Poorman Formation.

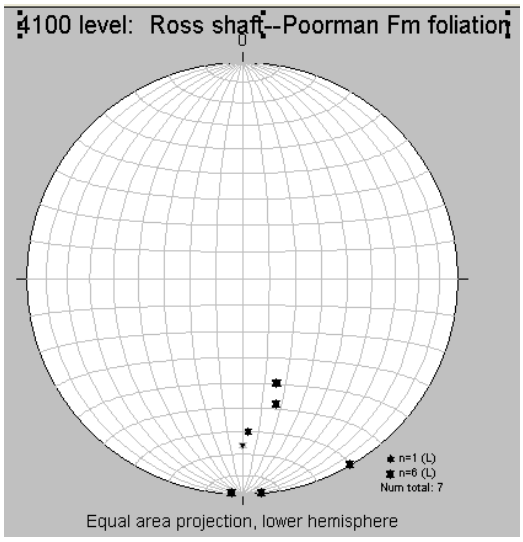


Location A-4. 4100 level Yates shaft area Yates unit (amphibolite).

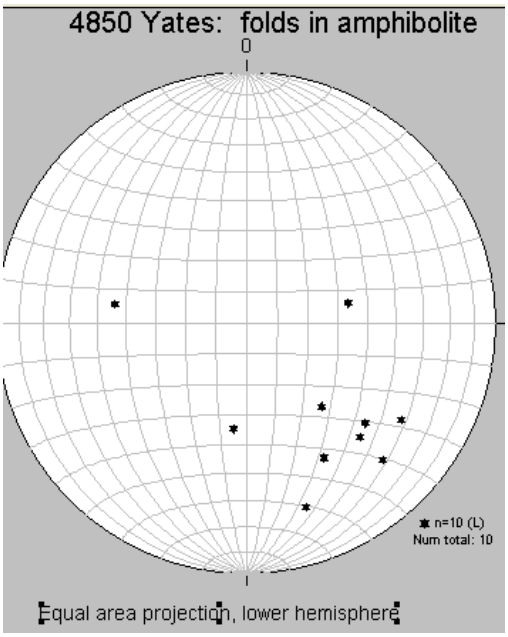


Surface exposure of Yates unit (amphibolite) along Blacktail Gulch road. Blue lines are foliation/layering: black lines are fractures; Pink triangles are mineral lineations.

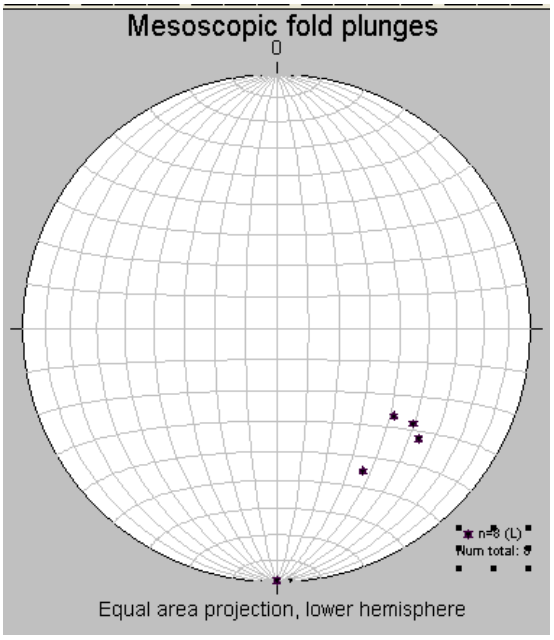
Figure II.8. Fractures in the Poorman Formation and Yates unit (amphibolite) in drifts on the 4100 and 4850 levels. Locations shown on Figure II.6.



Location A-1. 4100 level, Ross shaft area, Poorman Formation. For three horizontal dots no plunge values are shown on map.



Location A-4. 4850 Yates shaft, Yates unit amphibolite



Location 3. Poorman Formation, 4100 level south, near Yates unit contact.

Figure II.9. Stereonets showing plunges of mesoscopic folds in the Poorman Formation and the Yates unit (amphibolite) shown on geologic maps from the 4100 and 4850 levels.

C. *Poorman Formation*

The Poorman is a thin-bedded mass of phyllite/schist (e.g., Fig.II.5-H) that is locally strongly folded one scales of one to 10's of feet. In addition to the foliation/layering, there are several other discontinuities, e.g., fractures (some filled with calcite, gypsum, quartz, and/or pyrite) and contacts with the Tertiary rhyolite dikes.

1. Contact relationships

Poorman Formation/Yates unit

See the description for the Yates unit given above.

Poorman/Tertiary rhyolite dikes

As seen in core and in exposures along the 4100 level, the contacts of amphibolite with rhyolite dikes are annealed. A thin, fine-grained zone of recrystallization extends outward a few inches into the amphibolite and the margins of the dikes are extremely fine-grained (almost porcelain-like). The contact zone is undulatory at scales ranging from a few inches to tens of feet along the strike length of the dike.

2. Foliation/layering

Foliation/layering trends within the Poorman Formation, as shown on geologic maps of the 4100 and 4850 levels, contrast greatly across the Lead anticline. They are *much* more deformed than is the upper contact of the Yates unit, but with similar southeast fold plunges. The wavelengths of folds are less, the numbers greater, and there is only a general parallelism of the surface of the Yates unit with the interpreted Homestake Formation contained within the Poorman (e.g. Fig. II.2).

4100 Level

On the 4100 level foliation/layering measurements in the east limb of the anticline are remarkably parallel internally and with the upper contact of the Yates unit. The average strike and dip is N.9°E, 48°SE. (4100 Level Geologic Map; Fig.s II.6 and II.7-A3; Table 1).

Similar parallelism is also present along the crest of the Lead anticline above the Yates/Poorman contact (Fig. II.6 and Fig. II.7-A3) in the drift south of the Yates shaft. The attitude of the foliation/layering is N.83°W, 32°SW. Further south along the axial zone of the anticline the foliation/layering trends generally north and dips east, but with many small folds (4100 Geologic Map)

Within the phyllite south of the contact between the Yates unit (amphibolite) and Poorman Fm. there are two generations folds. The earliest fold group identified (F1) are isoclinal folds with axial surfaces parallel to foliation. These folds and associated foliation were folded into inclined open to tight folds (F2) with east dipping axial surfaces (Fig. II.5H).. Both generations are southeast plunging at 20° to 30° consist with the bulk of compiled fold plunges on 4100 and 4850 levels.

Although the F1 folds have not been identified in the Yates unit, it is probable that they are present given that the foliation associated with the axial surface is very pervasive. The axial planar foliation which strikes approximately EW and dips at 20° to 30° near the contact with Yates unit is prone to the release of large blocks in the Poorman Formation.

West of the Lead anticline axis the degree of folding is indicated at the map scale by the complexity of the interpreted map pattern of the Homestake Formation (Pch-2) on the 4100 Level Geologic Map. At the smaller scale this complexity is shown in the area of the intersection of two drifts (4100 Level Geologic Map; Fig.II.6; Fig. II.7-A5 and A6) where the foliation generally trends N and dips 35°-40°W. Mesoscopic-scale folding of the layers (Fig. II.5-H) is shown on the map and indicated by the second, NE-trending, strike of layering on stereonet A5 which represents the shorter fold limb.

The area of strongest folding (4850 Level Geologic Map) is along a 200 foot-wide zone extending eastward from the Ross shaft. As shown on the geologic map, this entire width is deformed by south-plunging (Fig. II.9-A1) mesoscopic folds. This zone of strong Precambrian deformation trends N35^{o}W and, based upon the dips of fold limbs, is near vertical.

4850 Level

Drifts on the 4850 level cut the Poorman in the west limb of the Lead anticline (4850 Geologic Map). The trend of foliation/layering is north-northwest, dipping steeply to the southwest: There are isoclinal folds within this pattern. Very strong folding of the foliation/layering is present along the drifts within ~200 feet northeastward from the Ross shaft (Fig. II.5-A-1).

3. Shear zones/faults

The strongest deformation of the Poorman is mapped in the drifts (both 4100 and 4850) eastward from the Ross shaft and trends approximately N30^{o}W. This ~200 foot wide zone of strong folding is, perhaps, a wide zone of distributed shear formed during deformation in the Precambrian.

Only one fault is shown on the drift maps of the 4100 and 4850 levels. This fault, located on the 4100 level southeast of the Ross shaft, strikes N30^{o}W and dips to the northeast.

4. Main joint sets

As indicated on the geologic maps of the 4100 and 4850 levels, the trends of joint sets are variable across the anticline. Along the 4100 drift northeast of the Yates shaft (the east limb of the Lead anticline) a single set of calcite-filled fractures trends N.17°W with an average dip of 62°W (Fig. II-8A-3; Table 1). In contrast, two vertical fractures sets are present near the Ross shaft (Fig.s II.6 and II.8A-1; Table 1) at the 4850 level with average

tends of N68^{o}E. and N30^{o}W. Additional fractures trend ENE and dip gently to moderately NW and NNW with a moderate NE dip.

D. Rhyolite dike swarm

1. Trend of the dike swarm

An ~700 foot-wide swarm of Tertiary rhyolite dike crosses the central portion of the study area with a trend of N.20°W. Measurements from drill core and along the 4100 and 4850 drifts suggest that between 20% and 35% of the zone consists of dikes. Six to eight dikes are present in transects across the swarm.

2. Geometry of individual bodies

Individual dikes generally trend parallel to the zone noted above and dip steeply northeast. Based upon the exposures in the Open Cut surface mine and limited lateral control from the 4100 and 4850 drifts it seems that continuity of these dikes along strike is highly variable. Some are "fingers" a few tens of feet in length (but extending upward and downward), others are a hundred feet long or more in plan view. They tend to terminate at blunt margins. The width of individual bodies varies as well, from a foot or so to as much 120 feet (although this latter figure may be a composite for several individual, but touching, bodies).

3. Contact relationships

The contacts of dikes are irregular surfaces, even on the scale of inches, and are annealed with their country rock. Near dikes crests and the blunt lateral margins, there are breccias composed of angular to rounded clasts of rhyolite and Precambrian country rock (T. Trancynger, personal communication, 2009). Those observed by the authors are also annealed into competent masses. The margins of the dikes tend to be very fine-grained, apparently as a result of chilling following emplacement, and have a porcelaneous character.

4. Joints

On the 4100 level the dikes are fractured and have well developed joint sets similar to the Yates unit. In contrast to the Yates unit, these joints have very smooth surfaces and may be prone to failure. The contacts are very rough and well annealed and appear to be very competent. As shown in Figure II.4, however, rhyolite samples in the core from DH#11553 and DH#11537 is more intensely fractured than is the enclosing amphibolite country rock.

5. Faults

No faulting of dikes is shown on the geologic maps.

II. 3-D GEOLOGIC MODEL

Preparation of the "3-D Geologic Model" of the Large Cavity Study Area in VULCAN (to be undertaken separately from this study) requires compilation of two-dimensional maps and cross sections. For this effort 16 cross sections oriented N53^{o}E. (viewed from the southeast) were constructed as were geologic maps of the 3950, 4100, 4250, 4550, 4850 and 5000 mine levels. Three additional maps, a structure contour map of the top of the Yates unit (amphibolite) and the 4100 and 4850 drift geologic maps with stereonets showing compiled features, were also prepared. All are at a scale of 1"=100'.

These maps and sections show the upper contact of the Yates unit, the boundaries of the area of the rhyolite dike swarm, and the two units of the Homestake Formation (one overlying the Poorman Formation, the other enclosed within it), and the zone of strongly folding (shear?) near the Ross shaft. Where detailed geologic mapping of the drifts allows, interpretations of the foliation, individual dike locations, etc. are place on the sections as well. Such detailed information cannot be projected with certainty to adjoining sections due to uncertainties about the lateral extent of features in these complexly deformed rocks. .

These maps and sections provided the basis for preparation of the following diagrams which illustrate our current understanding of the geology of the Large Cavity area. In addition to the structure contour map of Figure II.1, Figure III.1 is a map view of the 4850 level (near the base of the proposed cavity sites) and Figure II.2 is cross section along a northeast-trending line linking the Ross and Yates shaft. The diagrammatic block model illustrating the three-dimensional relationships of the various large components (Fig. III.2) was constructed using all of the maps and sections..

II.1 3-D Model of the Large Cavity block

1. As shown on the geologic maps (e.g., Fig. II.1), the Precambrian country rock of the study area is divided along a NW-trending line at the 4850 level into equal parts. On the northeast is the Yates unit (amphibolite), on the southwest the Poorman Formation.

2. Most of the study area lies in the southwest limb of the Lead anticline. Foliation/layering trends NNW in the amphibolite with dips less that 70°SW, averaging in the 30°s. The orientation of foliation/layering in the Poorman Formation may dip generally southwest, but is much more complex due to folding.

3. The 4700 structure contour line represents the southwest boundary of the area in which at least 100 feet of amphibolite would overlie the top of proposed caverns (~4800 ft) if they are placed within the Yates unit (amphibolite).

4. The zone of complex, mesoscopic folding in the Poorman Formation near to the Ross shaft may be less stable than other portions of the Poorman. The fold noses may be subject to a greater degree of fracture.

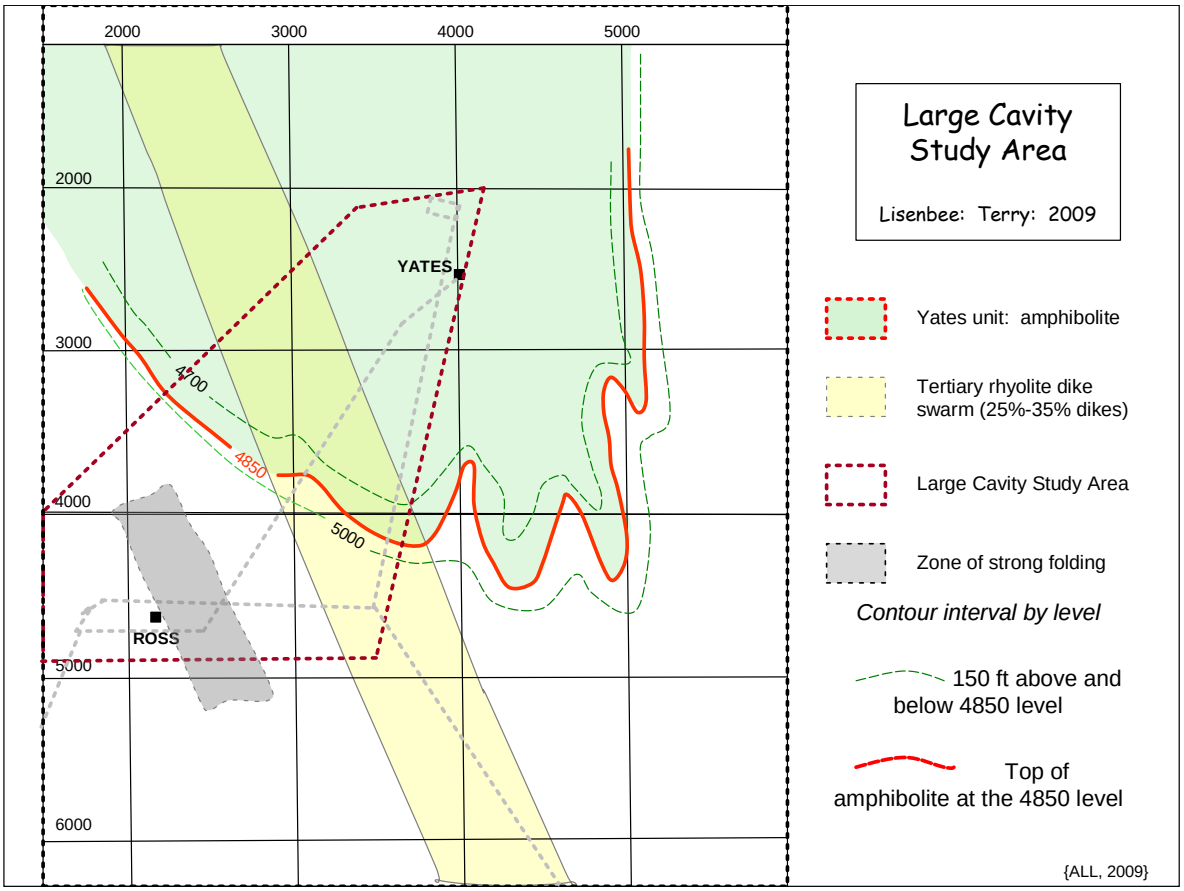


Figure III.1. Significant geologic features of the 4850 level. The Large Cavity study area is divided approximately equally, at the 4850 level, into the Yates unit (northeast) and Poorman Formation (southwest). The study area is crossed in the middle section by a NNW-trending zone of steeply dipping Tertiary rhyolite dikes (generally six to eight in number) and on the southwest by a zone of strongly folded (at the mesoscopic and large scale) phyllite of the Poorman Formation. The study area is located chiefly in the southwest limb of the Lead anticline. The axial crest of the southeast-plunging fold lies a few hundred feet west of the Yates shaft.

5. The 700 foot wide, N20^{o}W-trending swarm of rhyolite dikes (with 20%-35% dikes) crosses the study area such that it invades more of the amphibolite that the Poorman phyllite.

6. Limited data suggest that the rhyolite behaves in a more brittle fashion relative to the amphibolite.

7. The contact of the rhyolite with Yates unit and with Poorman Formation seems to be well annealed.

8. The contact of the Yates unit and Poorman Formation is a zone of considerable breakage as seen on the 4100 level.

9. Fractures are ubiquitous. They occur in multiple sets, along with the foliation planes in the Precambrian strata. The trends derived from the drift maps are variable with location and rock type. Due to the limited amount of data and this variability, delineation of specific areas of concern is not possible in this study.

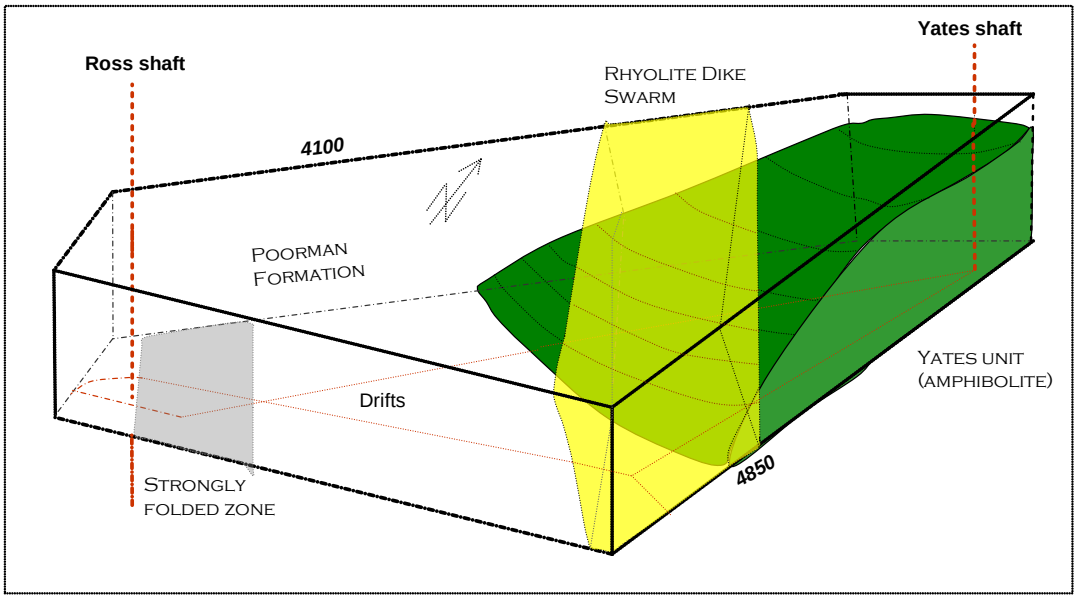


Figure III.2. Diagrammatic illustration of the 3-D Model of geology in the Large Cavity Study Area.

III. RECOMMENDED STEPS IN CONVERTING GEOLOGIC MAPS AND SECTIONS TO 3-D VULCAN FORMAT

- Digitize structure contours of the upper surface of the Yates unit (amphibolite) from structure contour map. Triangulate to form surface.

- Digitize the "Homestake Formation" (labeled PCh-2) in the geologic cross sections. Triangulate to show fold forms. This surface continues through only a portion of the model.

- Digitize the "Homestake Formation" (PCh-2) on the 4100 Level Geologic Map for comparison of the map pattern of the formation to that derived from cross sections

- Digitize individual areas on the 4100 and 4850 level Geologic Maps showing geologic detail (There are two copies of each of these level maps. One is generalized, one shows the geologic detail). Kathy Hart at DUSEL has digitized the geology mapped in the drifts. We show additional interpretations that will need additional digitization.

- Digitize the "Rhyolite dike swarm" in each of the 16 geologic cross sections. Triangulate to form a block.

- Edit the dike swarm triangulation to insure relatively smooth continuity of the swarm margins

- Insert fracture data derived from stereonets (take averages from Table 1).

- Compile into a 3-D model and edit.

- The final version should bear some resemblance to Figure III.2

IV. ACKNOWLEDGMENTS

This project was possible only through the complete cooperation of members of the DUSEL staff at the Homestake Mine and the information which they supplied. These members include Dr. Jaret Heise, Ms. Kathy Hart, and Mr. Tom Trancynger. Thank you for the discussions, the maps, access to the core, and the underground trip. We also appreciate the confidence of Dr. Zbigniev Hladysz and Dr. William Roggenthen at the South Dakota School of Mines and Technology that allowed us the opportunity to prepare this study.

APPENDIX A . STEREONET DATA

Type: P = planar: L= Linear

1) 4100DPB (Label of digital version on CD) *(Location: 5400S + 3750E)*

DpDir	Dip	Type	Comments	Display points
155.0	32.0	P	4100 -- west from drift intersection: Foliation in Poorman	{Cross
72.0	39.0	P	4100 -- west from drift intersection: Foliation in Poorman	{Cross
2135.0	56.0	P	4100 -- west from drift intersection: Foliation in Poorman	{Cross
148.0	60.0	P	4100 -- west from drift intersection: Foliation in Poorman	{Cross 2
127.0	76.0	P	4100 -- west from drift intersection: Foliation in Poorman	{Cross 2
150.0	83.0	P	4100 -- west from drift intersection: Foliation in Poorman	{Cross 2
72.0	67.0	P	4100 -- west from drift intersection: Foliation in Poorman	{Cross 2
52.0	72.0	P	4100 -- west from drift intersection: Foliation in Poorman	{Cross 2
76.0	44.0	P	4100 -- west from drift intersection: Foliation in Poorman	{Cross 2
80.0	45.0	P	4100 -- west from drift intersection: Foliation in Poorman	{Cross 2
93.0	42.0	P	4100 -- west from drift intersection: Foliation in Poorman	{Cross 2
74.0	39.0	P	4100 -- west from drift intersection: Foliation in Poorman	{Cross 2
67.0	30.0	P	4100 -- west from drift intersection: Foliation in Poorman	{Cross 2
110.0	32.0	P	4100 -- west from drift intersection: Foliation in Poorman	{Cross 2

2) 4100RPB (*Location 4600S + 2150E to 5000S + 3000E)*

DpDir	Dip	Type	Comments	Display points	
73.0	82.0	P	4100-Ross Shaft area--Poorman Fm foliation	{Cross 2	-1
229.0	65.0	P	4100-Ross Shaft area--Poorman Fm foliation	{Cross 2	-
1180.0	16.0	P	4100-Ross Shaft area--Poorman Fm foliation	{Cross 2	-1
28.0	90.0	P	4100-Ross Shaft area--Poorman Fm foliation	{Cross 2	-1
29.0	90.0	P	4100-Ross Shaft area--Poorman Fm foliation	{Cross 2	-1
28.0	90.0	P	4100-Ross Shaft area--Poorman Fm foliation	{Cross 2	-1
180.0	30.0	P	4100-Ross Shaft area--Poorman Fm foliation	{Cross 2	-1
165.0	48.0	P	4100-Ross Shaft area--Poorman Fm foliation	{Cross 2	-
1169.0	50.0	P	4100-Ross Shaft area--Poorman Fm foliation	{Cross 2	-1
222.0	65.0	P	4100-Ross Shaft area--Poorman Fm foliation	{Cross 2	-1
56.0	85.0	P	4100-Ross Shaft area--Poorman Fm foliation	{Cross 2	-1
36.0	90.0	P	4100-Ross Shaft area--Poorman Fm foliation	{Cross 2	-1
38.0	90.0	P	4100-Ross Shaft area--Poorman Fm foliation	{Cross 2	-1
38.0	90.0	P	4100-Ross Shaft area--Poorman Fm foliation	{Cross 2	-1
76.0	90.0	P	4100-Ross Shaft area--Poorman Fm foliation	{Cross 2	-1
36.0	70.0	P	4100-Ross Shaft area--Poorman Fm foliation	{Cross 2	

3) 4100YAAM *(Location 2500S + 3900E)*

DpDir	Dip	Type	Comments	Display points	
19.0	45.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2	-1
200.0	50.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2	-1
7.0	60.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2	-1

0.0	70.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 --
1170.0	80.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
190.0	80.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
25.0	80.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	WATER CORSE
341.0	65.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
198.0	48.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
62.0	70.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
170.0	38.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -
1352.0	60.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
350.0	60.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
325.0	60.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
198.0	60.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
275.0	68.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
287.0	37.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -
1256.0	57.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
96.0	70.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
218.0	60.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
345.0	50.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
335.0	80.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
94.0	31.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
108.0	37.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
137.0	55.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2
130.0	40.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
348.0	70.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
347.0	75.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -
1351.0	70.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
350.0	70.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
115.0	38.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
118.0	38.0	P	4100 Fracs in Yates amphibolite near shaft --	{Cross 2 -1
112.0	38.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -
195.0	30.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
88.0	30.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1
92.0	32.0	P	4100 Fracs in Yates amphibolite near shaft --calcite	{Cross 2 -1

4) 4100 YANE *(Location 1950S + 4620E to 1550S + 5100E)*

DpDir	Dip	Type	Comments	Display points
264.0	53.0	P	4100 NE of Yates shaft – Fract in Poorman Fm phyllite	{Cross 2
260.0	52.0	P	4100 800-1200 ft NE– Frac in Poorman Fm phyllite	{Cross 2
255.0	56.0	P	4100 800-1200 ft NE Yates shaft -- Fract in PCp phyllite	{Cross 2
255.0	63.0	P	4100 800-1200 ft NE Yates shaft – Fract in PCp phyllite	{Cross 2
258.0	63.0	P	4100 Fractures in Poorman Fm phyllite	{Cross 2
247.0	65.0	P	4100 Fractures in Poorman Fm phyllite	{Cross 2
247.0	62.0	P	4100 Fractures in Poorman Fm phyllite	{Cross 2
253.0	55.0	P	4100 800-1200 ft NE of Yates shaft -- Fract in PCp	{Cross 2

260.0	68.0	P	4100 800-1200 ft NE -- Fractures in Poorman Fm phyllite	{Cross 2
96.0	55.0	P	4100 800-1200 ft NE of Yates shaft -- Fractures phyllite	{Cross 2
255.0	70.0	P	4100 800-1200 ft NE Yates shaft -- Fracts in Poorman Phyllite	{Cross

5) 4100 YAPL *(Location 1950S + 4620E to 1550S + 5100E)*

DpDir	Dip	Type	Comments	Display points
88.0	48.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2
82.0	52.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross
101.0	52.0	P	4100-NE from Yates shaft -- Layer/foliat Poorman	{Cross 2
102.0	52.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2
103.0	48.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2
95.0	55.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2
102.0	65.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2
86.0	66.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2
85.0	60.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2
93.0	60.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2
87.0	50.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2
90.0	54.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2
95.0	64.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2
91.0	57.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2
92.0	52.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2
102.0	47.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2
100.0	43.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2
87.0	40.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2
90.0	40.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2
106.0	43.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2
115.0	48.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2
107.0	46.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2
107.0	48.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2
109.0	48.0	P	4100 -- NE from Yates shaft -- Layer/foliation in Poorman	{Cross 2

6) 4100 YPFL *(Location 4600S +2150E to 5000S + 3000E)*

DpDir	Dip	Type	Comments	Display points		
178.0	30.0	L	4100 Ross Shaft area -- mesoscopic fold plunges	{Star	8	-
1180.0	24.0	L	4100 Ross Shaft area -- mesoscopic fold plunges	{Star	10	-
1175.0	1.0	L	4100 Ross Shaft area -- mesoscopic fold plunges	{Star	10	-1
183.0	1.0	L	4100 Ross Shaft area -- mesoscopic fold plunges	{Star	10	-1
162.0	48.0	L	4100 Ross Shaft area -- mesoscopic fold plunges	{Star	10	-1
165.0	40.0	L	4100 Ross Shaft area -- mesoscopic fold plunges	{Star	10	-1
150.0	1.0	L	4100 Ross Shaft area -- fold plunges -Poorman formation-	{Star	10	

7) 4100 YPFS *(Location 3950E + 3300S)*

DpDir	Dip	Type	Comments	Display points
192.0	45.0	P	4100 Yates -Poorman foliation south of Yates unit contact	{Cross 2
184.0	30.0	P	4100 Yates -Poorman foliation south of Yates unit contact	{Cross 2
193.0	45.0	P	4100 Yates -Poorman foliation south of Yates unit contact	{Cross 2
197.0	52.0	P	4100 Yates -Poorman foliation south of *Yates* unit contact	{Cross 2
182.0	32.0	P	4100 Yates -Poorman foliation south of Yates unit contact	{Cross 2
194.0	35.0	P	4100 Yates -Poorman foliation south of Yates unit contact	{Cross 2
164.0	34.0	P	4100 Yates -Poorman/Yates unit contact	{Cross 2

8) 4100YSPF *(Location 3950S + 3300E)*

DpDir	Dip	Type	Comments	Display points
82.0	55.0	P	4100 Yates -- drift intersect (S) : Foliation in Poorman	{Cross 2
82.0	32.0	P	4100 Yates -- drift inter (S) Foliation in Poorman	{Cross 2 -1
77.0	34.0	P	4100 Yates -- drift inter (S): Foliation in Poorman	{Cross 2 -1
79.0	42.0	P	4100 Yates -- drift intersection to south: Poorman Folia	{Cross 2
75.0	56.0	P	4100 Yates -- drift intersection to south: Poorman folia	{Cross 2
90.0	30.0	P	4100 Yates -- drift intersection to south: Poorman folia	{Cross 2
126.0	29.0	P	4100 Yates -- drift intersection to south: Poorman Folia	{Cross2
148.0	34.0	P	4100 Yates -- drift intersection to south: Poorman folia	{Cross 2
133.0	24.0	P	4100 Yates -- drift intersection to south: Poorman Folia	{Cross 2
90.0	40.0	P	4100 Yates -- drift intersection to south: Poorman Folia	{Cross 2
91.0	35.0	P	4100 Yates -- drift intersection to south: Poorman Foliat	{Cross 2
100.0	35.0	P	4100 Yates -- drift intersection to south: Poorman Folia	{Cross 2
117.0	30.0	P	4100 Yates -- drift inter to south: Foliat Poorman	{Cross 2

9) 4850FLD *(Location 2500S + 3900E)*

DpDir	Dip	Type	Comments	Display points
138.0	53.0	L	Bearing and plunge of isoclinal fold	{Star
278.0	46.0	L	Yates shaft (south) PCy amphibolite	" {Star
135.0	24.0	L	"	{Star
162.0	24.0	L	"	{Star
130.0	38.0	L	"	{Star
79.0	56.0	L	"	{Star
187.0	55.0	L	"	{Star
135.0	36.0	L	"	{Star
122.0	28.0	L	"	{Star
150.0	38.0	L	Bearing and plunge of isoclinal fold	{Star

10) 4850YAMP *(Location 2500S + 3900E)*

DpDir	Dip	Type	Comments	Display points
262.0	80.0	P	4850 Yates shaft -- Yates unit -- amphibolite folia/bedding	{Cross 2
265.0	60.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
177.0	44.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
167.0	24.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
160.0	50.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
170.0	29.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
221.0	72.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
257.0	77.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
232.0	44.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
109.0	48.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
208.0	84.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
155.0	39.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
170.0	31.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
135.0	32.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
109.0	43.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
122.0	17.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
113.0	46.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
103.0	64.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
105.0	55.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
92.0	45.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
118.0	35.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
115.0	22.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
137.0	36.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2
136.0	34.0	P	4850 Yates shaft -- Yates unit -- amphibolite foliat/bedding	{Cross 2

11) 4850YAT *(Location 2350S + 4000E to 1950S +2600E)*

DpDir	Dip	Type	Comments	Display points
175.0	32.0	L	4850 level. East drift	{Star
262.0	80.0	P	4850 level. East drift	{Cross 2
265.0	60.0	P	4850 level. East drift	{Cross 2
177.0	44.0	P	4850 level. East drift	{Cross 2
167.0	24.0	P	4850 level. East drift	{Cross 2
160.0	50.0	P	4850 level. East drift	{Cross 2
170.0	29.0	P	4850 level. East drift	{Cross 2
221.0	72.0	P	4850 level. West drift	{Cross 2
257.0	77.0	P	4850 level.	{Cross 2
232.0	44.0	P	4850 level.	{Cross 2
109.0	48.0	P	4850 level.	{Cross 2
208.0	84.0	P	4850 level.	{Cross 2
155.0	39.0	P	4850 level.	{Cross 2
170.0	31.0	P	4850 level.	{Cross 2
135.0	32.0	P	4850 level.	{Cross 2
109.0	43.0	P	4850 level. West Drift	{Cross 2

113.0	46.0	P	4850 level. Yates shaft	{Cross 2
103.0	64.0	P	4850 level. Yates shaft	{Cross 2
105.0	58.0	P	4850 level. Davis Chamber north of Yates shaft	{Cross 2
108.0	62.0	P	4850 level. Davis Chamber north of Yates shaft	{Cross 2
105.0	55.0	P	4850 level. Davis Chamber north of Yates shaft	{Cross 6
92.0	45.0	P	4850 level. Davis Chamber north of Yates shaft	{Cross 6
118.0	35.0	P	4850 level. Davis Chamber north of Yates shaft	{Cross 6
115.0	22.0	P	4850 level. Davis Chamber north of Yates shaft	{Cross 6
137.0	36.0	P	4850 level. Davis Chamber north of Yates shaft	{Cross 6
136.0	34.0	P	4850 level. Davis Chamber	{Cross 6

12) 4100RSFR *(Location 4600S + 2150E to5000S + 3000E)*

DpDir	Dip	Type	Comments	Display points
79.0	90.0	P	4850 Fract/calcite --Ross shaft 600 ft SE--Poorman FM	{Cross 2
162.0	90.0	P	4850 Fract/calc 600 from Ross SE Poorman	{Cross 2
62.0	90.0	P	4850 Fract/cacl 600 From Ross shaft	{Cross 2
169.0	15.0	P	4850 Fractures/calcite 600 ft SE From Ross shaft	(Cross 2
157.0	90.0	P	4850 Fractures/calcite 600 SE From Ross shaft	{Cross 2
154.0	90.0	P	4850 Fractures/calcite 600 ft SE From Ross shaft	{Cross 2
156.0	90.0	P	4850 Fractures/calcite 600 ft SE From Ross shaft	{Cross 2
157.0	90.0	P	4850 Fractures/calcite veins 600 ft SE From Ross	{Cross 2
49.0	45.0	P	4850 Fractures/calcite veins 600 ft SE From Ross	{Cross 2
355.0	15.0	P	4850 Fractures/calcite veins: 600 ft SE From Ross	{Cross 2
333.0	50.0	P	4850 Fractures/calcite veins: 600 ft SE From Ross	{Cross 2
90.0	80.0	P	4850 Fractures/calcite veins: Ross shaft to 600 ft to SE	{Cross 2
169.0	90.0	P	4850 Fractures/calcite veins: Ross shaft to 600 ft to SE	{Cross 2
107.0	90.0	P	4850 Fractures/calcite veins: Ross shaft to 600 ft to SE	{Cross 2
154.0	90.0	P	4850 Fractures/calcite veins: Ross shaft to 600 ft to SE	{Cross 2
162.0	90.0	P	4850 Fractures/calcite veins: Ross shaft to 600 ft to SE	{Cross 2
157.0	90.0	P	4850 Fractures/calcite veins: Ross shaft to 600 ft to SE	{Cross 2
52.0	90.0	P	4850 Fractures/calcite veins: Ross shaft to 600 ft to SE	{Cross 2
64.0	90.0	P	4850 Fract/calc 600 SE Ross	{Cross 2
335.0	39.0	P	4850 Frac/calc 600 SE or Ross Poorman Fm	{Cross 2