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PAPER/PRESENTATION

NO. 11

PIT WALL MINING UNDERGROUND AT CURRAGH'S FARO OPERATION

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PIT WALL MINING UNDERGROUND AT CURRAGH'S FARO OPERATION

By L.R. Hwozdyk

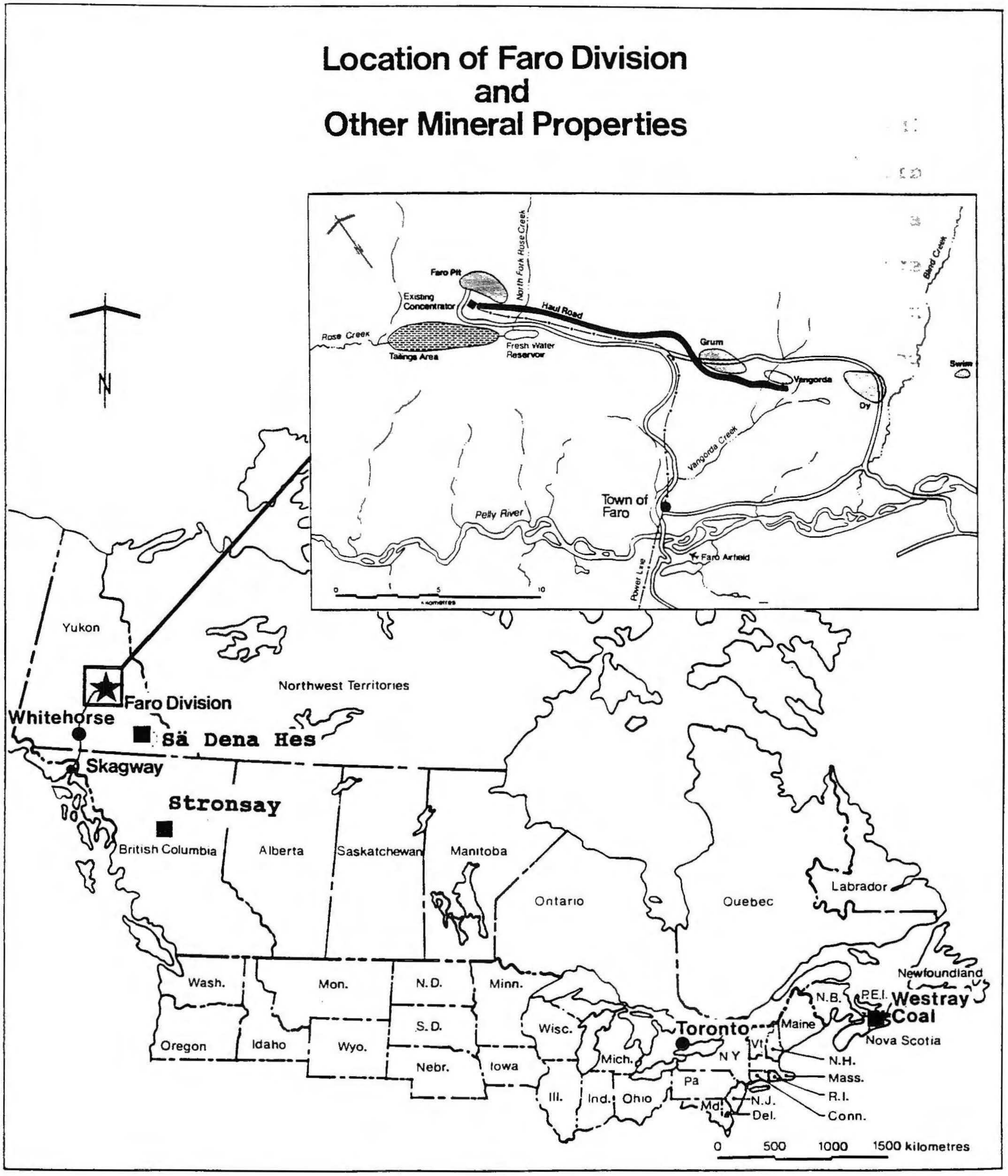
ABSTRACT

At Curragh's Faro open-pit mine, a tabular shallow dipping extension of lead-zinc bearing ore, located in the west wall of the open pit, could not be economically recovered by open pit methods due to the high stripping ratio. It was determined, however, that 1.2 million tonnes of ore grading 6.17% zinc and 4.08% lead could be economically extracted by underground room and pillar methods and thus extend mine life and improve the aggregate cash flow. This paper will review the decision making process that went into establishing and operating an underground mine in conjunction with a fully active open pit mine, as well as some of the challenges the project faced before and after the start-up.

INTRODUCTION

The Company's zinc-lead mining operations are located in Yukon, and include the Faro and Sa Dena Hes divisions, Figure 1. Both divisions mine and concentrate zinc and lead ores from open-pit and underground mining operations, producing zinc and lead concentrates which are then transported to world markets, primarily smelters in Asia and Europe.

Location of Faro Division and Other Mineral Properties



- ● Office
- ■ Mineral Property
- ★ Faro Division

Figure 1

The Faro mine is located in the Anvil Range zinc-lead-silver-gold district within the Selwyn Basin in central Yukon. The zinc-lead-silver-gold deposits of the Anvil Range are of a sediment-hosted, stratiform, massive pyritic sulphide type. There are presently four known zinc-lead bearing mineral deposits along a curvilinear path comprising of the Faro, Grum, Vangorda and Dy deposits.

Mineralization was discovered in the Faro area in the late 1950s. In the late 1960s, the Anvil Mining Corporation Ltd. was formed to complete the exploration and development of the Faro deposit and to direct the design and construction of mining and milling facilities at Faro. Mining operations were started in 1969 and milling commenced in 1970. In the mid 1970s, exploration by others began on the Vangorda and Grum deposits. Cyprus Anvil Mining Corporation Ltd., the successor corporation to Anvil Mining Corporation Ltd., ceased operations at the Faro mine in 1982 for financial reasons. From 1970 until operations ceased, a total of approximately 33.1 million tonnes of ore was mined from the Faro mine.

The Faro operation is a self-contained mining complex that includes open-pit and underground mines, a concentrator, maintenance facilities, offices and warehouse and other facilities for mining and concentrating zinc and lead ores. The Faro operation contains four major bodies: Faro, Grum, Vangorda and Dy. All of these bodies are located within 13 miles of the Faro concentrator, with the Faro deposit being the closest at one-half mile and the Dy deposit being the most distant. The company's mine, concentrator and shipping facilities operate 24 hours per day, 365 days per year, with only one maintenance location shutdown taken since restarting the mine in 1986

In 1987 a zone of two (2) millon tonnes of high grade lead-zinc ore located in the west wall of the pit was defined by surface diamond drilling. The zone was determined not to be mineable by open-pit methods. Also, time to mine the zone was limited due to the long-range tailings disposal plan scheduling tailings disposal into the mined out pit in 1992. In the following two years, 1988 and 1989, two separate drilling programs and several studies were undertaken to evaluate the geological and geotechnical data obtained. Final approval to develop the underground mine in the wall of the pit was given in November of 1989. Following completion of the surface shop facilities on a prepared pad in the pit, the portal was collared in late 1989 and mining commenced January 5, 1990.

GEOLOGY

The Faro deposit is hosted by late Precambrian to Paleozoic metasedimentary and metavolcanic rocks, intruded by a Cretaceous granitic plutonic suite, Figure 2.

The district has a complex deformational and metamorphic history.

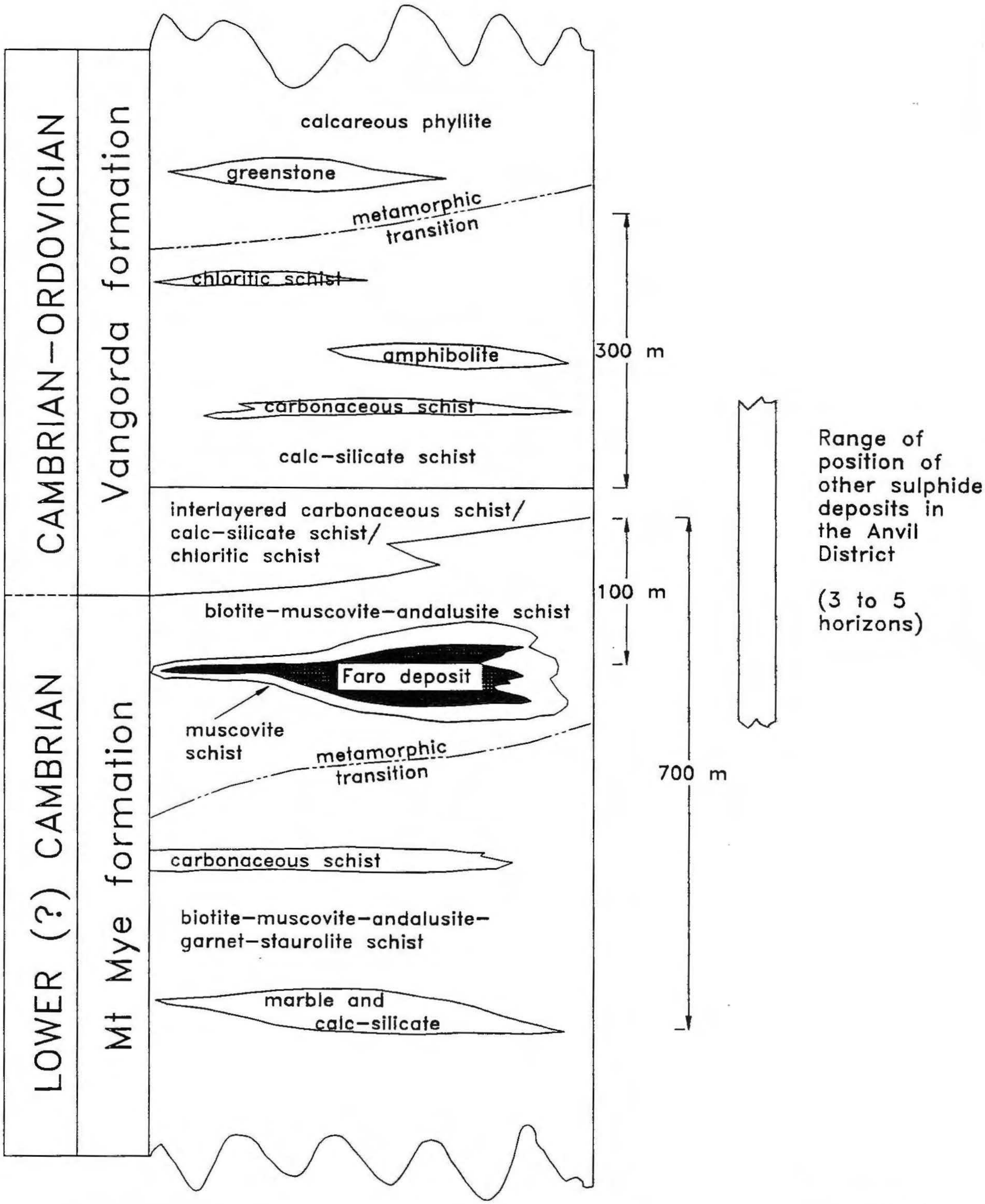


Figure 2

F.G.C.

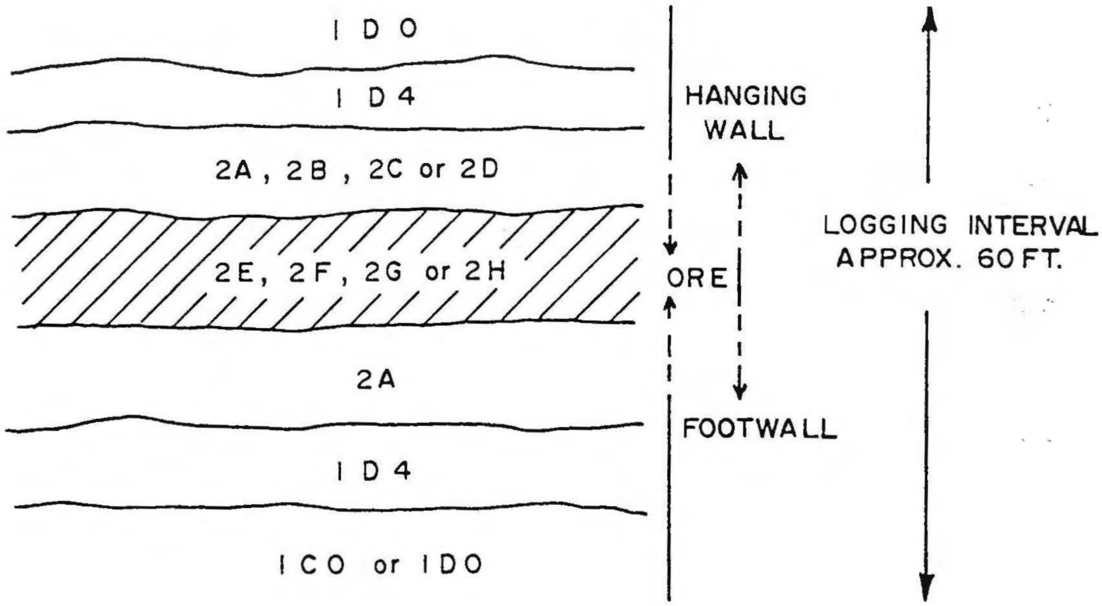
CURRAGH INC.	DRAWN BY: I. BILQUIST, 21/09/92	STRATIGRAPHIC SECTION OF THE FARO DEPOSIT
	FILE: ANVLSTRA AUTOCAD V. 11	

Two overlapping Mesozoic regional folding events, as well as subsequent non penetrative folding and faulting, have been recognized. Rocks have been metamorphosed to the greenschist and amphibolite facies.

The mineralization occurs in the uppermost Mt. Mye formation of Late Proterozoic and Lower Cambrian age. The Faro deposit is a stratiform, stratabound, pyritic massive sulfide deposit of probable synsedimentary, exhalative origin.

Underground development within the sulphide horizon consisted of extraction of ore grade massive pyritic/pyrrhotitic sulphide. Hanging wall lithology is dominately low-grade uneconomic disseminated pyritic sulphide in quartzite. Muscovite biotite schist is the hanging wall in local areas. Footwall material is mainly low-grade carbonaceous quartzite. The sulphide horizon is hosted by muscovite, biotite, andalusite schist which is altered to white muscovite schist near the orebody.

Figure 3 is a generalized cross section of the underground orebody showing the mineralized zone and the immediately surrounding hanging wall and footwall rocks. This package of rocks reaches a maximum thickness of about 60 ft (18 m). The white mica envelope will control roof stability where it occurs within the hanging wall.



GEOLOGIC LEGEND

Faro Pit Mineralized Rocks

Unit 2
- A Sulfide-bearing, ribbon-banded, graphitic quartzite
- B Pyrite-free quartzite (may contain base metal sulfides)
- C Base metal-poor, pyritic quartzite
- D Base metal-bearing, pyritic quartzite
- E Massive pyritic sulfides
- F Buckshot facies, massive sulfides
- G Baritic facies, massive sulfides/sulfates (>10%:$BaSO_4$)
- H Pyrrhotitic facies, massive sulfides
  - 2 Pyrite-bearing
  - 4 ZnS and/or PbS-bearing
  - 0 Normal

Faro Waste Rocks

Unit 1
- C Quartzo-feldspathic, biotite - muscovite gneiss/schist
- D Carbonaceous biotite-muscovite-andalusite schist
  - 4 Altered, pyritic (wme)*
  - 0 Normal

*(wme) white mica envelope

CURRAGH RESOURCES INC.	FARO UNDERGROUND	DATE NOV. 1988
SIMPLIFIED SECTION THROUGH ORE ZONE		PROJ. NO. 60610
		APPROVED
		NO. Figure 3
STEFFEN ROBERTSON & KIRSTEN, Consulting Engineers		

GEOMETRY OF THE ZONES

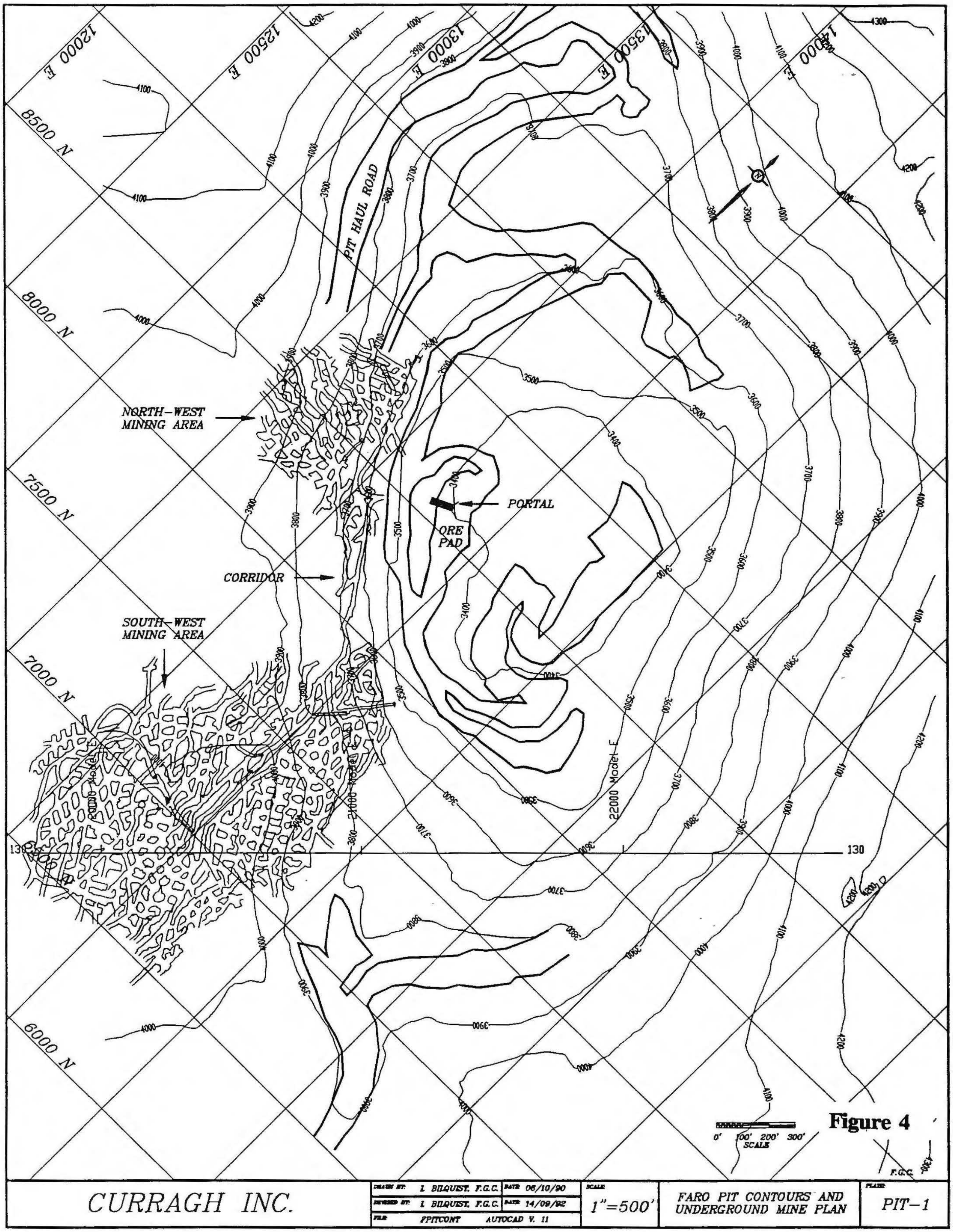
On the west wall of the open pit, 525 ft. (160 m) from surface is a tabular extension of the Faro orebody which is divided into three part all of which dip at a shallow angle into the pit wall; the northwest area, the corridor area, and the southwest area, Figure 4.

The northwest area has approximate dimensions of 500 ft (150 m) by 500 ft (150 m) and reserves within it were defined by five surface diamond drill holes. This limited data indicated that the area contained three structural blocks with an average thickness of 13 ft (4 m).

The corridor area was tested by fourteen surface diamond drill holes. From the information gathered from these holes, one structural block was interpreted which had an average thickness of 13 ft (4m). This block lies at the same elevation as the northwest and southwest areas, and forms a connection between them.

The southwest area was defined by fourteen diamond drill holes which outline a block of 1000 ft (300 m) square and 18 ft (5.5 m) thick. It contained numerous tight folds. Average dip varies between 16 - 22 degrees.

Some preliminary structural interpretation was attempted from the


12000 E
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13000 E
13500 E
14000 E
8500 N
8000 N
7500 N
7000 N
6000 N
PIT HAUL ROAD
NORTH-WEST
MINING AREA
PORTAL
ORE
PAD
CORRIDOR
SOUTH-WEST
MINING AREA
21000 Model E
22000 Model F
130
0' 100' 200' 300'
SCALE
F.G.C.
CURRAGH INC.
DRAWN BY: L BILQUIST. F.G.C.
DATE: 06/10/90
REVISED BY: L BILQUIST. F.G.C.
DATE: 14/09/92
FILE: FPITCONT AUTOCAD V. 11
SCALE 1"=500'
FARO PIT CONTOURS AND
UNDERGROUND MINE PLAN
PLATE PIT-1

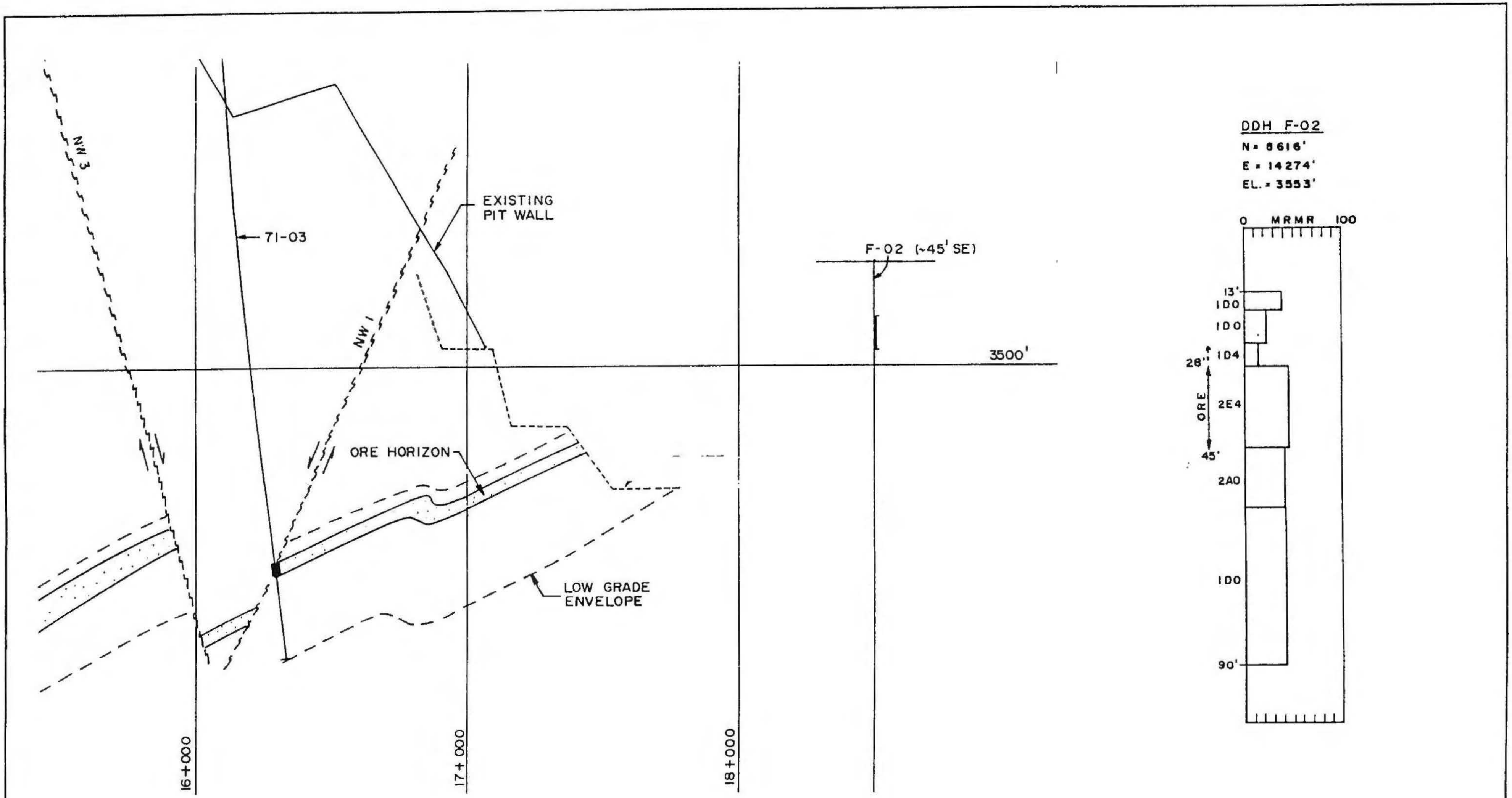
Figure 4

1988 Faro surface/underground drilling program as shown in Figure 5. Sparse drilling density precluded the possibility of resolving detail structure. However, complex folding and faulting was recognized. Apparent vertical fault displacements of several meters are common and can cause problems during mining.

Two options were available to obtain the additional information needed to make a production decision: a closer surface drilling pattern could be used, or an underground exploration development program could be implemented. The latter approach had several advantages over dense drilling. Not only would it provide accurate structural data, but also information on roof stability, water conditions and an insight into applicable mining methods. As well, any ore mined would be processed to offset the costs of exploration.

SURFACE INSTALLATION

Portal location was determined after reviewing the haul road layout of the final pit, design along with ore contacts along the pit wall and local faulting. The plans required that fill be placed along a section of the wall to construct the haul road going to the pit bottom. This fill would cover the portal entrance by 15 ft (4.6 m); therefore, in order to maintain the portal opening, an 18-ft (5.5m) diameter culvert had to be installed and the backfill carefully



LEGEND

ORE INTERCEPT RECENT DRILLING

PREVIOUS INTERPRETATION

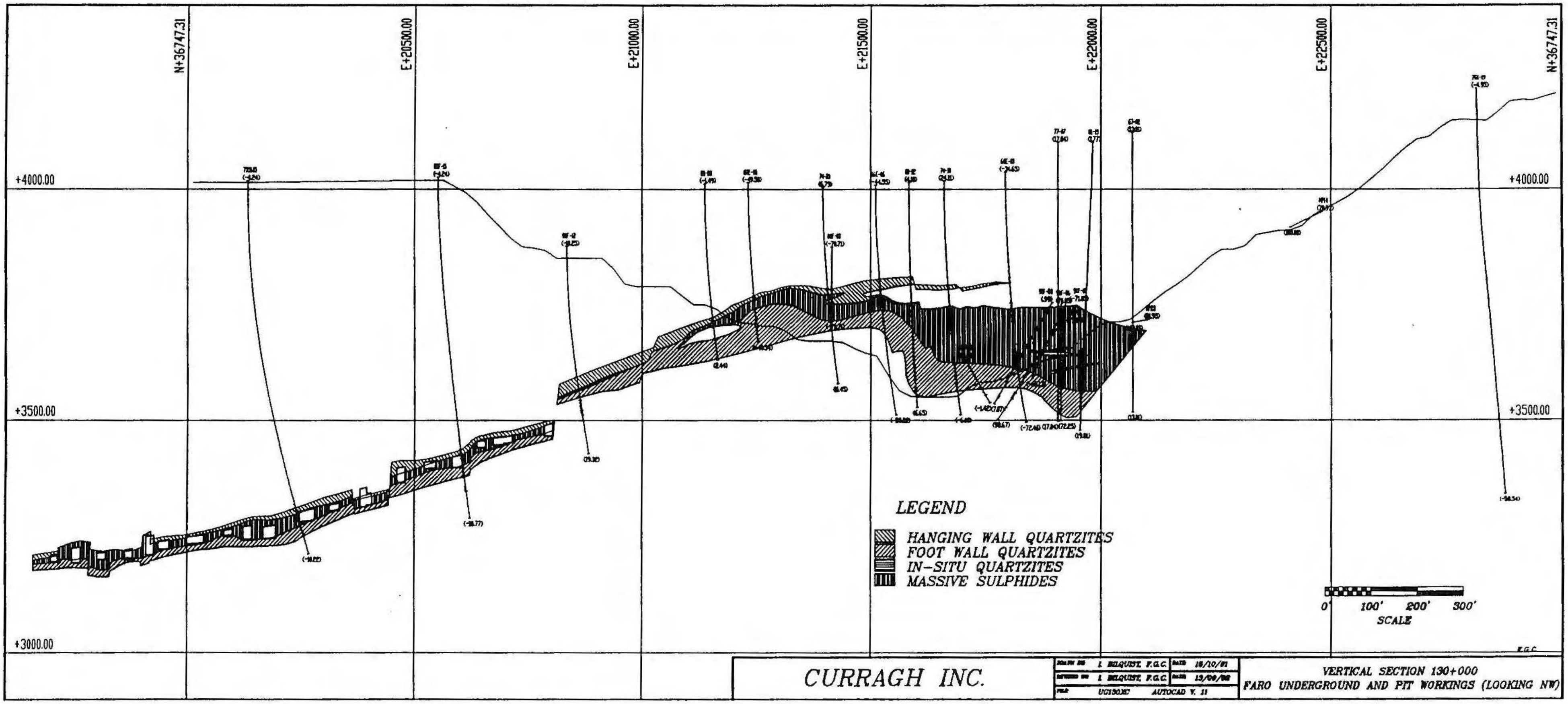
CURRAGH RESOURCES INC. FARO UNDERGROUND	DATE NOV. 1988
	PROJ. NO. 60610
SECTION 120 + 000 (AS PER MORRIS, 1988)	APPROVED
	NO.
STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	**Figure 5**

placed over the top of it. This allowed for access to the bottom of the pit while maintaining the portal to the underground workings.

Surface installations requiring completion prior to mining underground were as follows: erect a maintenance shop for servicing 16 pieces of mobile equipment; establish a ventilation and mine air heating system; establish a separate mine entrance and stockpile area from the existing open-pit operations; establish a camp and dry facilities in preparation for crew mobilization.

SELECTION OF MINING METHOD

The dip of the ore zone is between 15 and 25 degrees. Thickness varies from between 10 ft (3m) and 50 ft (15 m), with the bulk of the reserves averaging approximately 29 ft (9 m) in thickness. The reserves were based on a total of 23 surface drill holes spaced approximately 140 ft (43 m) apart. Mineable reserves were identified as 1.2 million tonnes (diluted by 10 percent), representing 60 percent extraction. The dip was relatively flat, and therefore, best suited for room and pillar methods as shown in Figure 6.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+3000.00
LEGEND
HANGING WALL QUARTZITES
FOOT WALL QUARTZITES
IN-SITU QUARTZITES
MASSIVE SULPHIDES
0' 100' 200' 300'
SCALE
CURRAGH INC.
VERTICAL SECTION 130+000
FARO UNDERGROUND AND PIT WORKINGS (LOOKING NW)
AUTOCAD V. 11

Figure 6

PILLAR DESIGN

Pillars were designed using an empirical relationship derived from research carried out in Canada and South Africa. Tall pillars are much weaker than short pillars of the same cross-sectional area. The rock mass strength is a function of the quality of the rock mass (the number and character of the geologic structure) as well as the intact strength of the rock. These two factors, pillar geometry and rock mass strength, are inputs into the empirical relationship which calculates pillar strength. Pillar loads are calculated from the weight of rock overlying each pillar. This is a conservative approach and is periodically checked using computer analysis techniques. A factor of safety is applied to the pillar layout to manage the risk inherent in the room and pillar method.

Based on pillar design formulae developed in Elliot Lake, Ontario, by Dave Hedley of Canmet, a modified design relationship was developed by Steffen, Robertson and Kirsten (B.C.) Inc. for use by site personnel:

$$\text{Safety factor} = \frac{\dfrac{8250\ W_{eff}^{0.5}}{H^{0.7}}}{\dfrac{1.1\ D\cos^2\alpha + (1.1\ D \times 2)\sin^2\alpha}{1-e}}$$

Where W_{eff} = effective pillar width (ft)

$$= \frac{4A_p}{R}$$

W = pillar plan area

A_p = pillar perimeter

H = pillar height, ft

D = depth below surface, ft

α = dip angle

e = percentage extraction/100

In conjunction with the above empirical formula, a numerical analysis of the underground layout was completed to give a better estimate of stresses by taking into account the presence of the open pit and the proximity of the abutments.

Generally, the design relationship was considered a reasonable estimate. There was insufficient mining area for the development of a site-specific relationship for Faro underground. An examination on March 18, 1991 of an initial mining area uncovered very minor pillar spalling, indicating that the pillars were beginning to take some weight.

MINE LAYOUT AND EXTRACTION

Major development prior to the start of production is shown on Figure 7 and comprises three main areas: the main access decline, the mining levels and the ventilation raise.

The access decline was collared on the northwest wall of the existing open pit at 1060 m elevation and driven downwards at a grade of 18 percent. Dimensions of the decline were 15 ft (4.6 m) high by 14 ft (4.3 m) wide. This decline was positioned to permit access to both the northwest and southwest blocks. With the exception of 400 ft (122 m), all development, amounting to approximately 3445 ft (1050 m), was done in ore.

Two main ventilation raises were driven - one in the end of the northwest block and the other in the middle of the southwest block - to provide fresh air to the mine. These raises also served as emergency escape manways. The main decline in the southwest area was twinned and driven at a maximum gradient of 18%; one heading served for haulage and the second for ventilation.

Panel development advanced on strike at 46-ft (14 m) centers, with the production stopes mined at right angles. Stope development was similar for both stopes in thick ore zones and stopes in thinner ore zones. Development was positioned in the ore to minimize the excavation of waste.

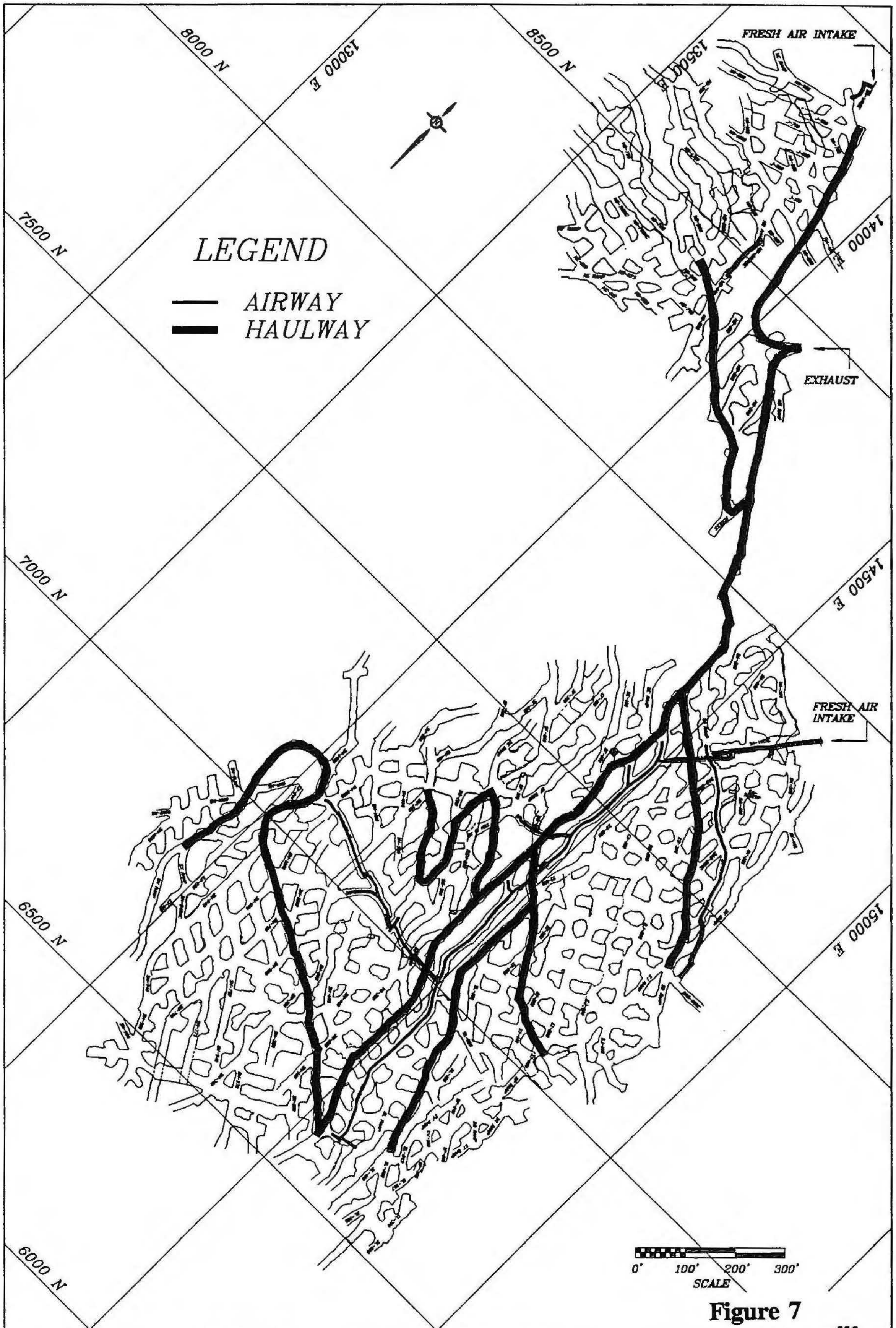


Figure 7

CURRAGH INC.	I. BILQUIST, F.G.C.	08/10/90	1"=300'	FARO U/G MINE PLAN WITH HAULWAY AND AIRWAY
	I. BILQUIST, F.G.C.	15/09/92		
	UGVWTHWY	AUTOCAD V. 11		

The typical configuration for mechanized room and pillar mining is illustrated in Figure 8. Pillar slashes of 30 ft (9 m) were taken on either side of the pillar for the room, followed by a breakthrough round. The pillar widths varied due to variation in the dip and thickness of the ore. If the ore thickness was greater than 18 ft (5.5 m), successive lifts of up to 18 ft (5.5 m) were benched down to the footwall.

In areas where dips or faulting resulted in a very steeply sloping roof as Figure 9 illustrates, the heading azimuth was changed to maintain the maximum gradient of 18%; however, ponding and varying pillar widths resulted. Ponding was generally short-lived until stopes were mined through from the panel below.

A total of 6 active stopes and 15 active development headings in ore was required to produce the scheduled 2200 mt per day.

ROOF STABILITY

In general, two back conditions were recognized, one composed of either quartzite and/or ore, the other composed of muscovite schist or metabasite.

In areas with quartzite in the back thicknesses greater then 5 ft, (1.5m) three support systems were used. These were: split sets,

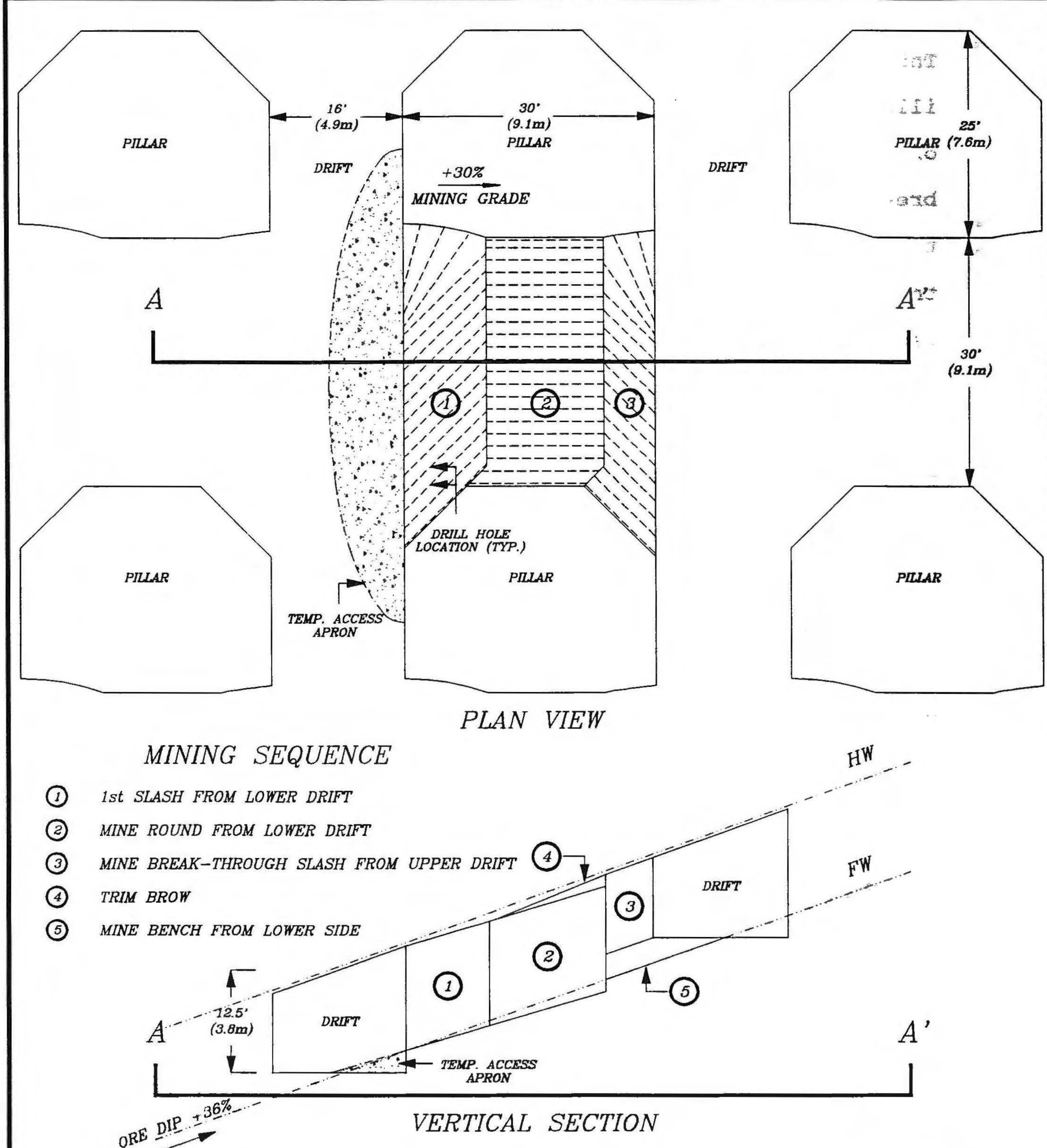


Figure 8 F.G.C.

CURRAGH INC.	DRAWN BY: I. BILQUIST, 17/09/92 FILE: STOPE AUTOCAD V. 11	TYPICAL SINGLE PASS 30'x30' UP-DIP STOPE

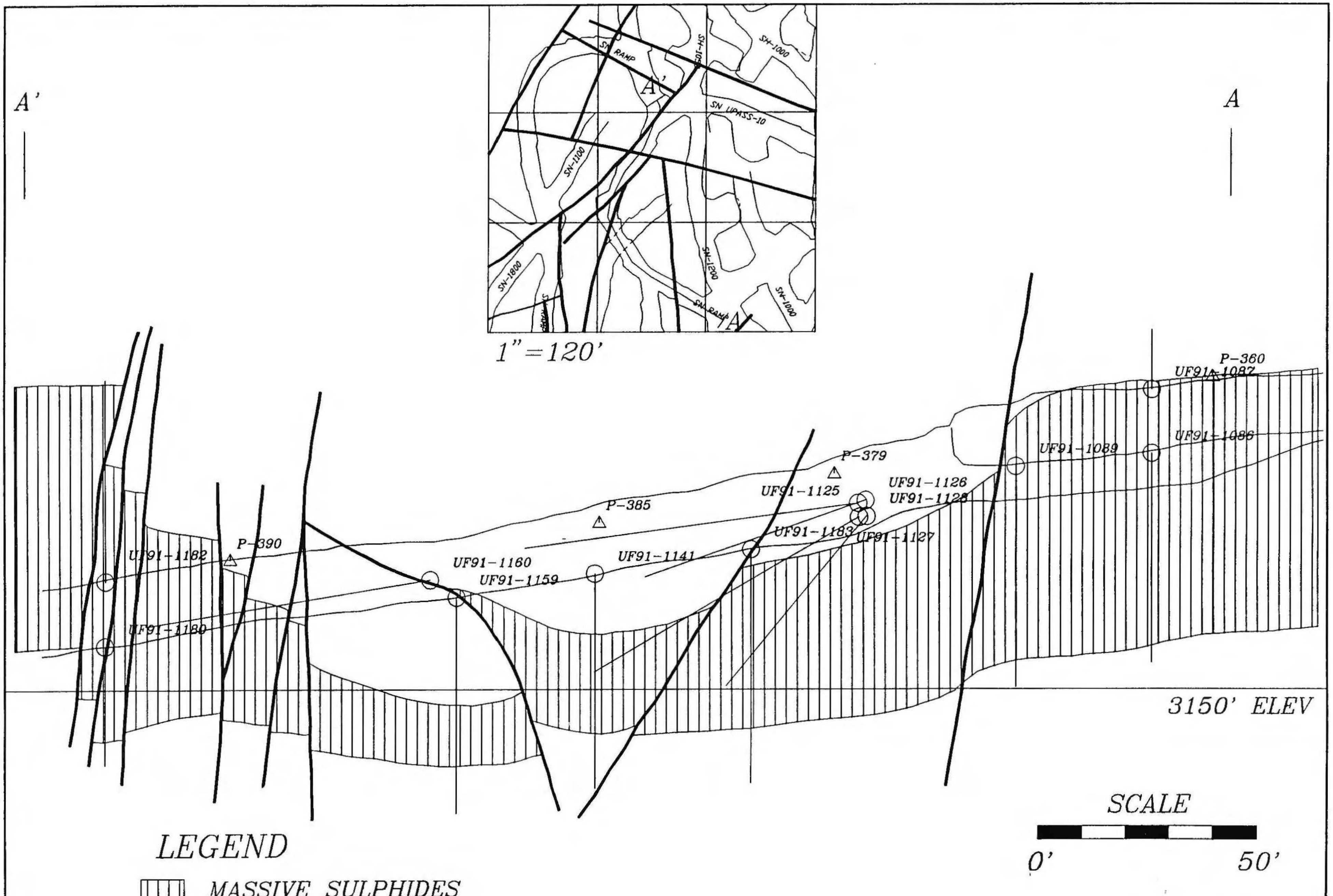


Figure 9

CURRAGH INC.	DRAWN BY: I. BILQUIST, F.G.C. 26/02/92	SN RAMP PROFILE
	SCALE: 1"=30'	

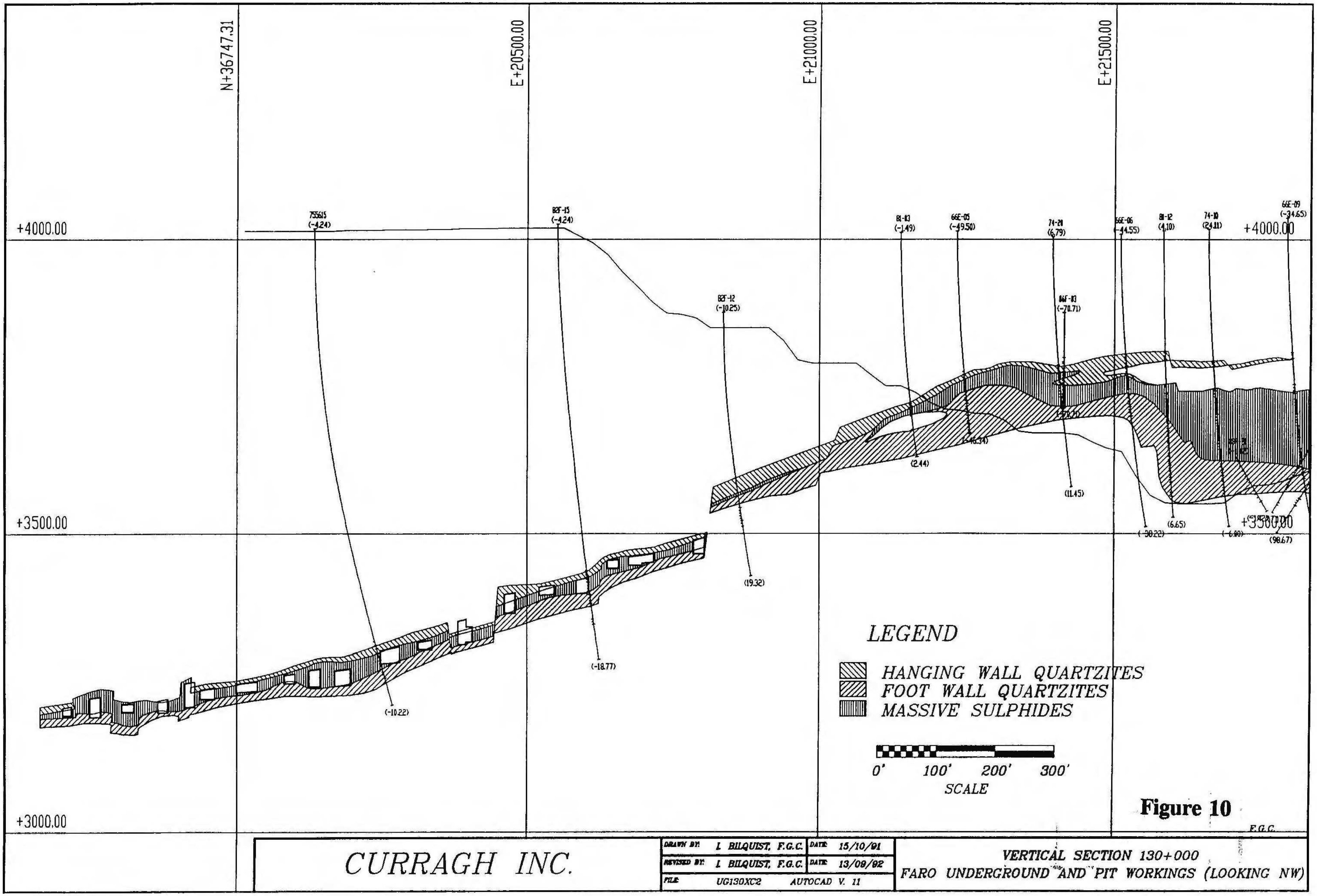
split sets with straps, and split sets with mesh and straps. Split sets, ss 39, length of 6 ft. (1.8m) and 8 ft.(2.4m) were used on an approximate 3.5-ft. (1.1m) square bolting pattern.

Backs with muscovite schist, located mostly in southwest limits of the mine as illustrated in Figure 10, a skim of ore, approximately 3 ft. (1m) was left in the back. Further, the mining spans of the rooms was reduced from 30 ft (9m) to 20 ft (6m) as shown in Figure 11. Longer split sets, 8 ft.(2.4m), were used in conjunction with straps and grouted rebar.

LOAD AND HAULAGE

Broken rock was removed from the face by an eight (8)-cubic-yard L.H.D machine and loaded into 26-ton capacity trucks. The ore was hauled to a stockpile area immediately outside the mine portal, where it was loaded into open-pit haulage trucks and hauled to a stockpile near the crusher. The initial waste was hauled to surface and disposed of in designated areas. Once sufficient space was created from mining, ore waste was stockpiled underground to reduce cost.

Removal of the surface stockpile material was carried out by a Letourneau L-1100 loader and a fleet of Euclid 170-tonne and 120-tonne Wabco trucks.



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E+21000.00
E+21500.00
+4000.00
+4000.00
+3500.00
+3000.00
LEGEND
HANGING WALL QUARTZITES
FOOT WALL QUARTZITES
MASSIVE SULPHIDES
0' 100' 200' 300'
SCALE
F.G.C.
CURRAGH INC.
DRAWN BY: I. BILQUIST, F.G.C.
DATE: 15/10/91
REVISED BY: I. BILQUIST, F.G.C.
DATE: 13/09/92
FILE: UG130XC2
AUTOCAD V. 11
VERTICAL SECTION 130+000
FARO UNDERGROUND AND PIT WORKINGS (LOOKING NW)

Figure 10

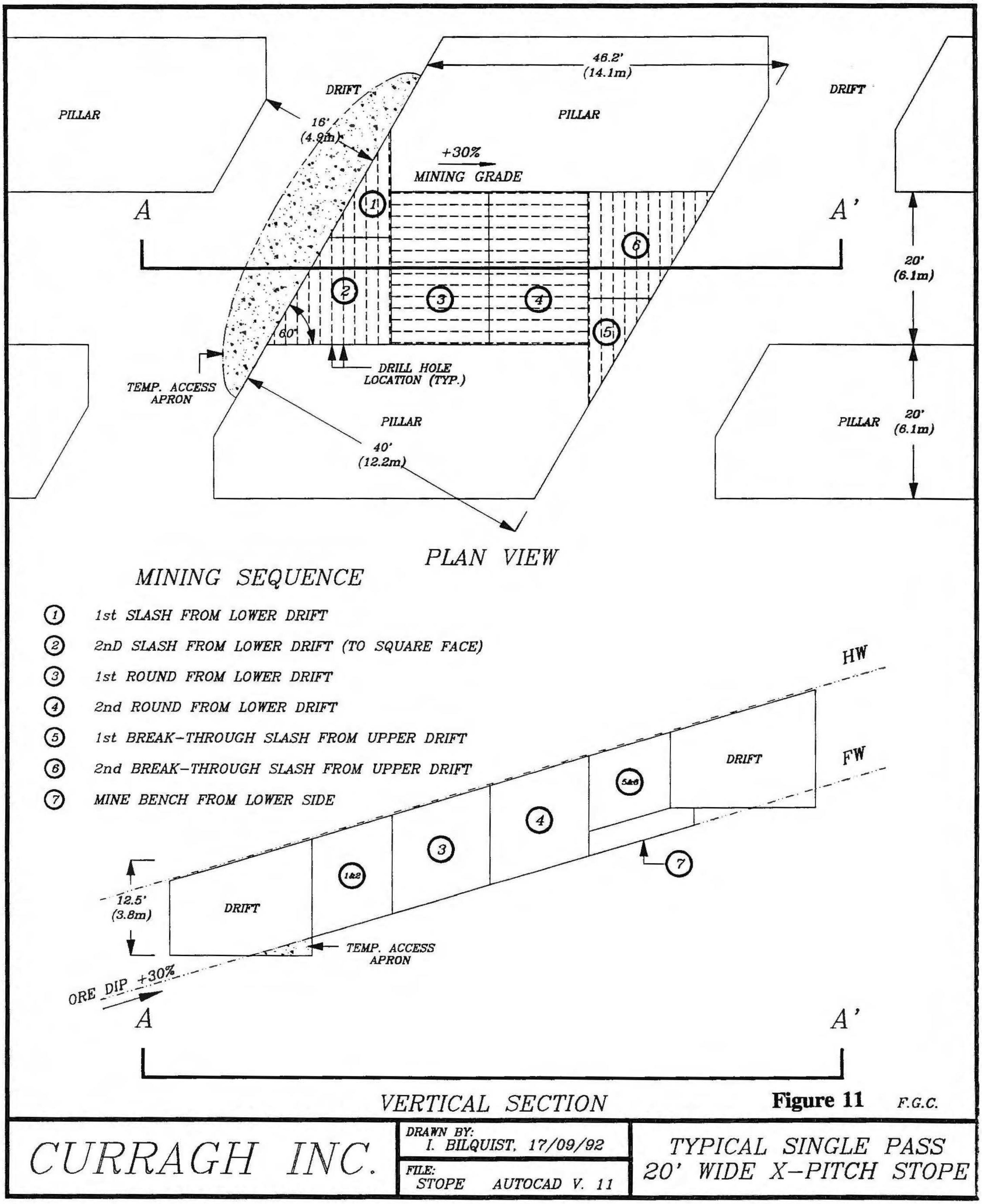
PILLAR
DRIFT
16'
(4.9m)
46.2'
(14.1m)
PILLAR
DRIFT
+30%
MINING GRADE
A
A'
1
2
3
4
5
6
20'
(6.1m)
60°
DRILL HOLE
LOCATION (TYP.)
TEMP. ACCESS
APRON
PILLAR
40'
(12.2m)
PILLAR
20'
(6.1m)
PLAN VIEW
MINING SEQUENCE
1 1st SLASH FROM LOWER DRIFT
2 2nD SLASH FROM LOWER DRIFT (TO SQUARE FACE)
3 1st ROUND FROM LOWER DRIFT
4 2nd ROUND FROM LOWER DRIFT
5 1st BREAK-THROUGH SLASH FROM UPPER DRIFT
6 2nd BREAK-THROUGH SLASH FROM UPPER DRIFT
7 MINE BENCH FROM LOWER SIDE
HW
FW
DRIFT
5&6
4
3
1&2
7
12.5'
(3.8m)
DRIFT
TEMP. ACCESS
APRON
ORE DIP +30%
A
A'
VERTICAL SECTION
F.G.C.
CURRAGH INC.
DRAWN BY:
I. BILQUIST, 17/09/92
FILE:
STOPE AUTOCAD V. 11
TYPICAL SINGLE PASS
20' WIDE X-PITCH STOPE

Figure 11

VENTILATION AND MINE AIR HEATING

The northwest and southwest blocks were separately ventilated as shown in Figure 7. The southwest system was down a raise into a dedicated airway which extended to the ore limits. Individual areas would pick up the air from the airway by means of an underpass or overpass. The northwest system, due to the relatively small area, was force-ventilated from the ventilation raise.

Ventilation requirements were dictated by the amount of diesel equipment operating within the mine, and in keeping with the ventilation regulation in the O.H.S.A of the Yukon. A total of six 48-inch, 75-hp fans provided the primary source and delivered 150,000 cfm of fresh air to the mine (two fans in the north ventilation raise and four fans in the south ventilation raise). The 75-hp fans were selected over larger 100+ hp fans as they prove more versatile in confined spaces; a further eight (8) to 10 fans ranging in size from 40 hp - 75 hp served as auxiliary fans.

The main ventilation fans were located at the bottom of each ventilation raise and positioned to allow ease of access for installation and maintenance. Within the mine, airflows to the working areas were controlled with auxiliary fans, ventilation tubing and bulkheads.

Direct-fired propane heaters were employed. The northwest system was fitted with a 4 million - BTU unit and the southwest block was serviced by a 7 million - BTU unit. Each ventilation system was equipped with a propane storage system.

EQUIPMENT

The operation at Faro used trackless equipment. The electric hydraulic jumbo consists of one Jarvis Clark three-boom jumbo with Montabert H-70 drills and a Tamrock two-boom jumbo with Tamrock 425 drills.

Loading of the three (3) 26-ton capacity trucks was performed by two Wagner ST-8A scooptrams and a Jarvis Clark J.S.500 scooptram. One Jarvis Clark Anfo loader, equipped with a 1000-lb tank was used for blast hole loading. Several intermediate Anfo loaders were also used.

Rockbolting was done with a Tamrock two-boom jumbo modified by C.M.D with operator's basket on one boom and a drill on the other. Secan stopers and jacklegs were used in both the development and production headings bolting off a platform on a J.S.- 220.

Service vehicles used included two 4x4 Kubota tractors for transporting supervision and maintenance personnel; a Getman Hiab

TABLE 1

The major pieces of equipment list is as follows:

1 - Three-boom electric hydraulic jumbo

1 - Two-boom electric hydraulic jumbo

1 - Anfo loading jumbo

1 - Intermediate loader

2 - 8 cu. yd. scooptram

1 - 5 cu. yd. scooptram

1 - 2.5 cu. yd. scooptram

3 - 26 cu. yd. truck

1 - Rockbolt jumbo

2 - Tractor type service vehicle

1 - D-3 dozer

1 - Boom truck

2 - 600 cfm compressor

flatbed truck with a boom-mounted hydraulic hoist, and one Caterpillar D-3 dozer. A more comprehensive equipment list is shown in Table 1.

MANPOWER

During the last year of the project the distribution of manpower was as follows:

56	miners
2	diamond drillers
3	geological consultants
1	company representative

Productivity for the mining crew was 41 mt per man shift while overall productivity for the project was 37 mt per man shift for muck delivered to the portal stockpile.

ECONOMIC STRATEGY

Due to the size of the reserves and the short life anticipated, the obvious question was whether Curragh should mine the extension or contract the work out. The answer was obvious.

The period of time involved - two years - was considered far too short for the company to make a commitment of additional capital for the necessary mobile and stationary equipment. Secondly, additional training personnel would be required to develop a high performance mining crew with no principal work for such personnal two years out.

Due to the uncertainty of the extension's physical characteristics, it was also important to have flexibility in both the manpower skills and the equipment fleet type and size. The mining contractor was better suited to provide the manpower skills and equipment needed to mine the extension as efficiently as possible.

Another challenge was to prepare and conclude a mining contract which would reflect the appropriate mining costs to make the program successful while maintaining flexibility for both parties.

ECONOMIC JUSTIFICATION

Based on the mineable reserves, a cash flow was developed. Considered as part of capital was erection of the culvert, setting up the shop and office complex opposite the portal in the pit, propane farm and development mining and diamond drilling of the first 400 ft (122 m) of waste.

Included in the operating costs were the mining, ore transportation from the pit to the crusher, milling, and concentrate handling which included trucking costs from mine site to the port as well as shipping.

For the revenue calculations, using the site's metallurgical performance, projected metal prices and payment condition, a positive cash flow was determined and justified the project proceeding.

SUMMARY AND CONCLUSIONS

The project will be completed in the middle of October 1992, with a total of 1,775,000 tonnes of ore at 4.45% Pb, 7.00% Zn and 70,000 tonnes of waste being mined or 2069 mtpd. The additional reserve of 575,000 was due to the ore thickening in the southern limits of the mine. The project's actual unit cost was favourable from initial estimates by a full 11%.

Retrieving pockets of ore from the pit wall by underground methods proved to be a successful project at Curragh's Faro operation. Not only was it a source of high-grade ore for the mill, it extended the mine life by approximately 4.25 months, and it maximized ore extraction from the deposit. Other benefits enjoyed by the mill were the contribution of a cleaner ore that was free of oxide material.

ACKNOWLEDGEMENT

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