Adams Barriere
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Exploration for Ag-Pb-Zn sulphide deposits in a multiply-deformed terrain in southern British Columbia

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ABSTRACT

Numerous Ag-Pb-Zn bearing sulphide deposits occur in a sequence of slightly metamorphosed sedimentary and volcanic strata of late Paleozoic age in south-central British Columbia. The deposits are stratiform in character but are discontinuous. The enclosing strata have a strongly developed foliation that is sub-parallel to lithologic boundaries and this foliation has often been mapped as bedding. Exploration for the sulphide deposits has been directed at intersecting the continuation of surface showings down-plunge in the plane of the foliation.

Mapping on a regional and detailed scale has shown that the foliation is parallel to the axial planes of isoclinal folds (F_1) and that bedding (S_0) can be at a high angle to the foliation at the fold hinges. Sulphide beds show some attenuation on the limbs of these F_1 folds and consequent thickening at the fold hinges. A second set of folds (F_2) with axes oriented east-west has also produced thickening of sulphide beds in minor folds, emphasizing the concentration of sulphides in structurally controlled positions. Minor thrust faults along and across the foliation have been observed on the small scale and are assumed to exist at a larger scale explaining some discontinuities in stratigraphy. Third phase folds (F_3) are open folds along north-south axial planes, are spatially related to normal faulting and have not had any significant effect on sulphide disposition.

In this structural setting the most likely location for a major sulphide accumulation would be in the hinge region of a large F_1 fold. Smaller deposits would be localised within F_2 folds. The target shape for sulphide deposit would be a linear, plunging body and exploration patterns must be directed accordingly.

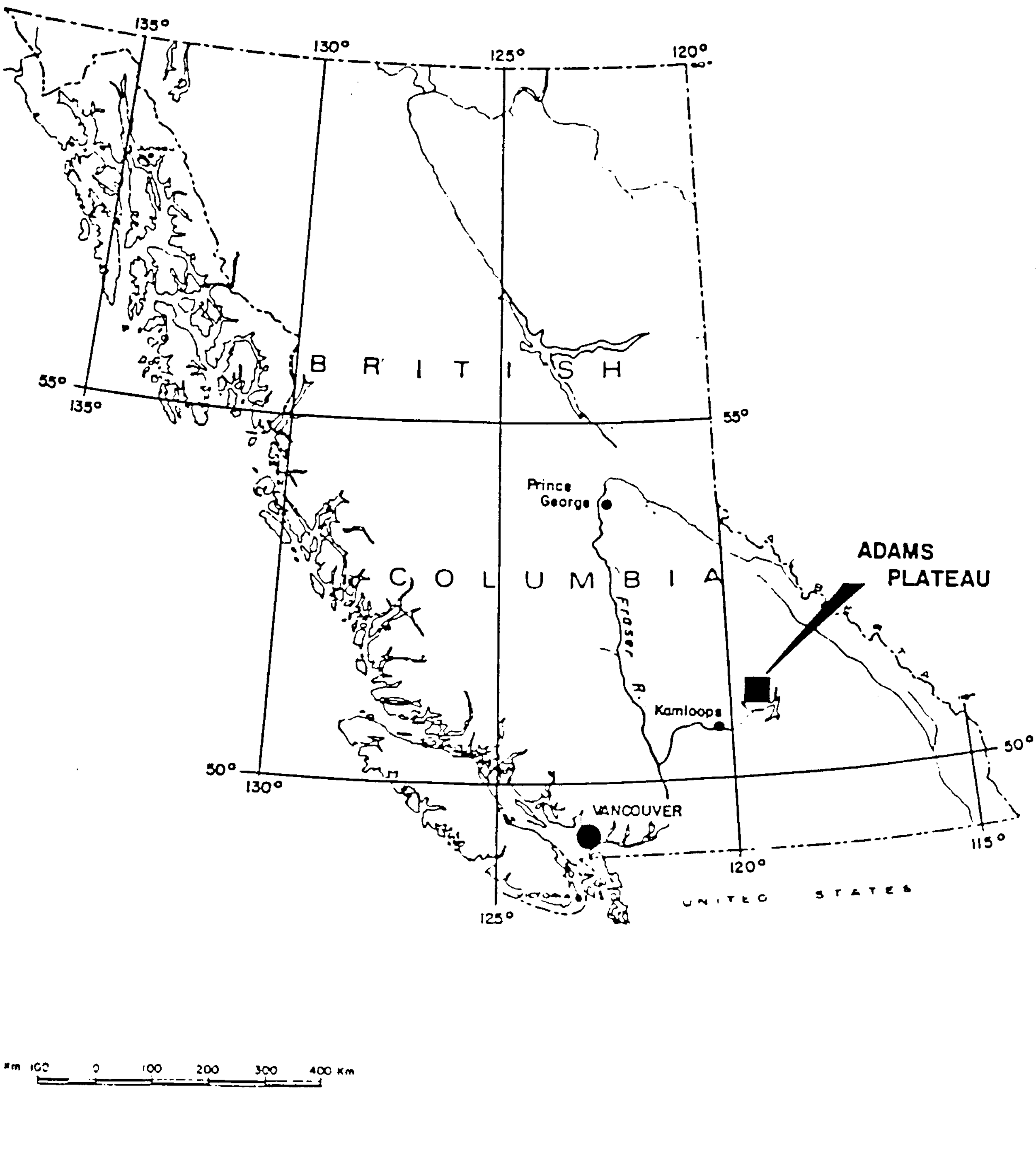
INTRODUCTION

The Adams Plateau is a steep-sided, gently rolling plateau averaging 750 metres elevation, located approximately 300km northeast of Vancouver, British Columbia (Figure 1). It occurs within the Omenica Crystalline Belt immediately adjacent to the Shuswap Metamorphic Complex (Figure 2).

Showings of Ag-Pb-Zn-Cu mineralization have been known on the Adams Plateau since about 1910. Subsequent exploration has been sporadic but since 1977 there has been an increase in exploration activity coinciding with a regional mapping program of the geological division, British Columbia Ministry of Energy, Mines and Petroleum Resources (Preto, et al., 1980, Preto, 1981). The regional mapping defined a stratigraphy which allowed delineation of three phases of folding. Results of this regional mapping were used as a framework for the more detailed scale of exploration described in this paper.

Outcrop on the Adams Plateau is limited because of the rolling topography and thick glacial till deposits. Most mapping information is acquired along logging roads and in bulldozer exploration trenches thus only a limited amount of three dimensional observation can be made.

Figure 1



135°
130°
125°
120°
55°
135°
BRITISH
55°
Prince George
ADAMS PLATEAU
COLUMBIA
Fraser R.
Kamloops
50°
50°
130°
VANCOUVER
115°
120°
UNITED STATES
125°
100 200 300 400 Km

REGIONAL GEOLOGY

The Paleozoic volcanics and sediments which contain the sulphide deposits are mapped as the Eagle Bay Formation (Okulitch and Cameron, 1976). It is in metamorphic and intrusive contact with the Shuswap Metamorphic Complex and granitic intrusions to the northeast, and in thrust contact with Mesozoic sediments and volcanics to the south and southwest (Figure 3).

Core gneisses in the Shuswap Metamorphic Complex have been dated at 2,000 + MA (Duncan, 1978), and some of the enfolded metamorphosed strata can be positively assigned early Paleozoic ages. Metamorphism of the Shuswap Complex has been speculated to be as young as Tertiary (Coney, 1979) which would suggest that there have been periods of metamorphism and deformation throughout the Paleozoic and Mesozoic.

The Mesozoic sediments and volcanics are considered to be part of the accreted terrains (Monger, et al, 1982) which were moved to their present positions along major strike-slip and local thrust faults during the late Mesozoic. The thrust contact of Figure 3 would then define the margin of the North American continent in Paleozoic and Mesozoic times.

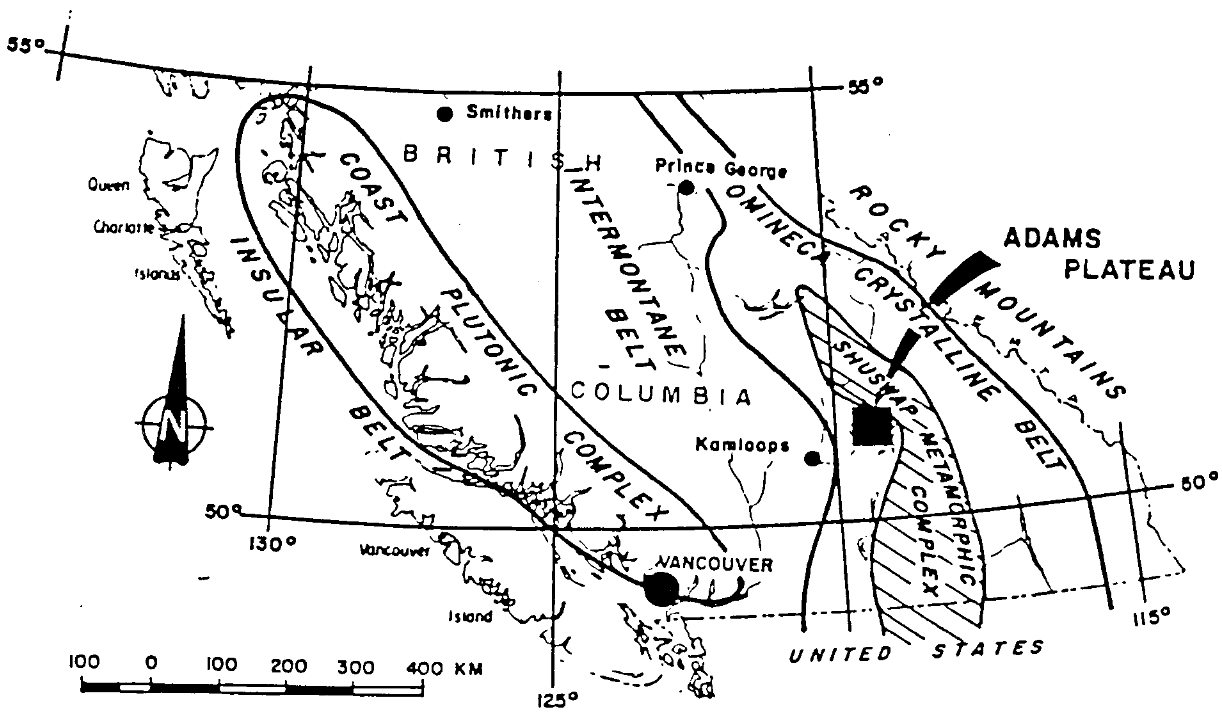
Eagle Bay Formation

Preto (1981) identified a great variety of rock types predominantly of sedimentary and volcanic origin within the Eagle Bay Formation. Because of the degree of metamorphism and the nature of outcrop it was not possible to establish a regional stratigraphic succession for the Eagle Bay Formation. Prominent distinctive members such as the Tshinakin Limestone, a white coarsely crystalline resistant limestone unit, can be mapped over significant distances and delineate the broad structural patterns. In most cases, lithologies are discontinuous along strike and definition of mappable units requires judicious amalgamation of lithologies.

Mississippian age conodonts were obtained from limestones and cherts towards the top of the Formation (Preto, 1981, Okulitch and Cameron, 1976) and a general consensus on a Devonian-Mississippian age is building but some workers still consider parts of the Eagle Bay to be as old as Cambro-Ordovician.

On the Adams Plateau the Eagle Bay Formation is predominantly volcanic (andesitic and rhyolitic) with a central core of sedimentary strata which host most of the sulphide showings (Figure 4). In the local stratigraphy established by Preto, the sedimentary strata overlie the andesitic volcanics and no evidence has been found to challenge this interpretation. The basic volcanics are now chloritic phyllite and greenschist, with textures indicating andesitic tuffs and flows with units of interbedded fine to coarse clastics. In some areas white coarse crystalline limestone beds occur within the greenschist sequence. The volcanics in the south consist of siliceous and sericitic phyllites which were originally rhyolites and rhyolite tuffs. There are some indications of chert layers within the sequence.

Figure 2


55°
55°
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115°
Smithers
BRITISH
COLUMBIA
Prince George
Kamloops
VANCOUVER
Queen
Charlotte
Islands
Vancouver
Island
COAST PLUTONIC COMPLEX
INSULAR BELT
INTERMONTANE BELT
OMINECA CRYSTALLINE BELT
ROCKY MOUNTAINS
SHUSWAP METAMORPHIC COMPLEX
ADAMS
PLATEAU
UNITED STATES
N
100 0 100 200 300 400 KM

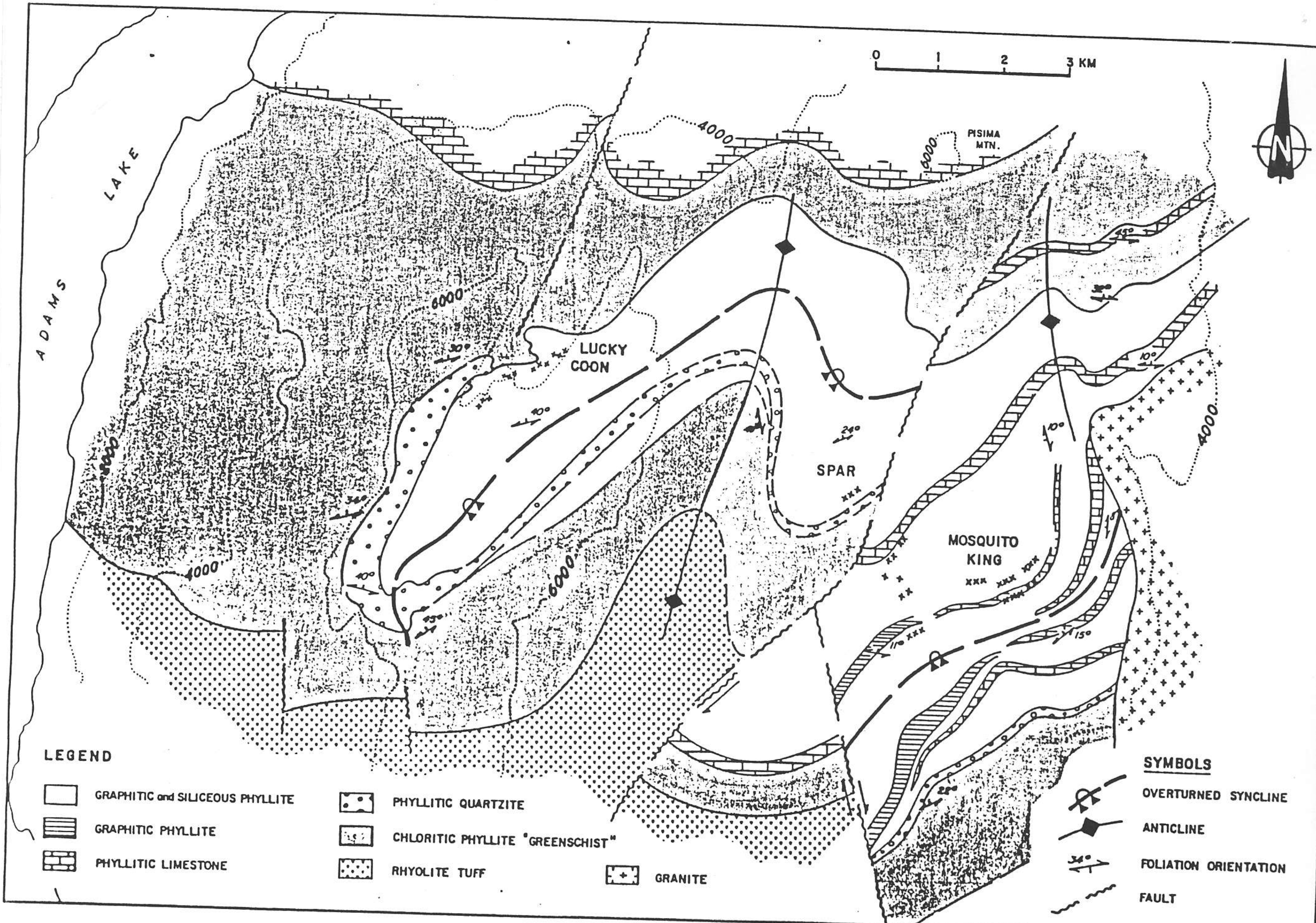


Figure 4

EXCLUSIVE DRAFTING SERVICES LTD

The overlying sedimentary sequence consists predominantly of graphitic to siliceous phyllite with layers of phyllitic limestone, green calcsilicate and black and white phyllitic quartzite. All lithologies in the sedimentary sequence with the exception of the phyllitic quartzite are discontinuous and the map units of Figure 4 are generalizations. However, on the scale of the Plateau, these lithologic units do define the large scale structural pattern. There is a facies variation in the dominant lithology from a black graphitic phyllite in the west to a brown, more siliceous phyllite in the east. Limestone units are more prominent and continuous in the east also which may indicate a shallowing of original depositional conditions from west to east.

The phyllitic quartzite is found in outcrop only on the south and west of the plateau, suggesting a facies change to a finer grain size in the north.

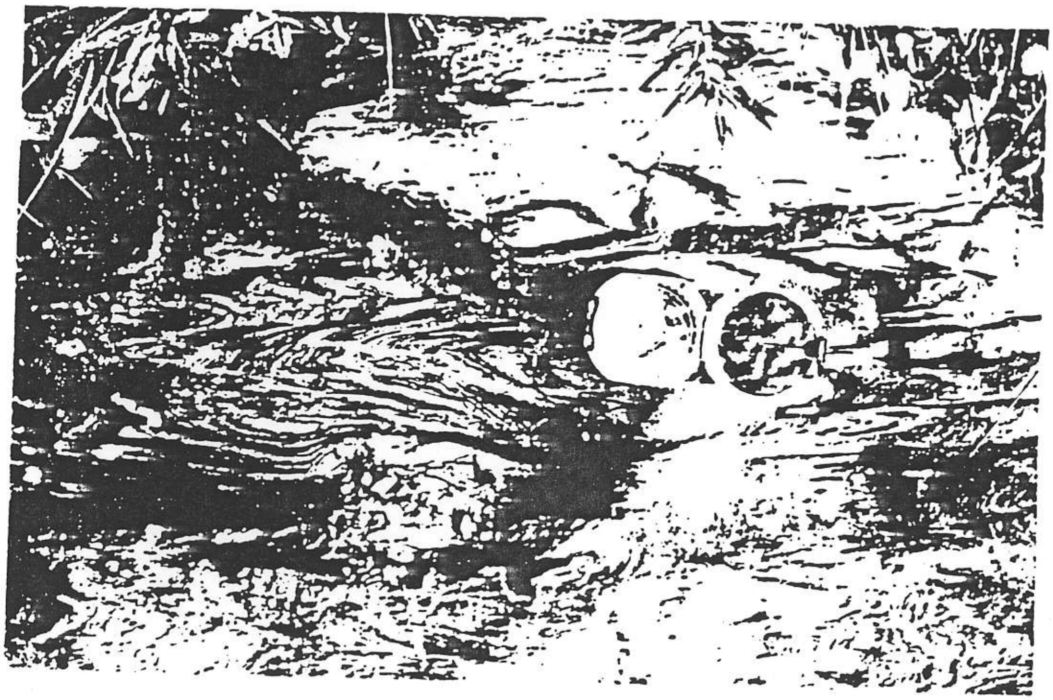
The Eagle Bay strata are truncated on the eastern end of the map area by a Cretaceous granitic intrusion.

SULPHIDE DEPOSITS

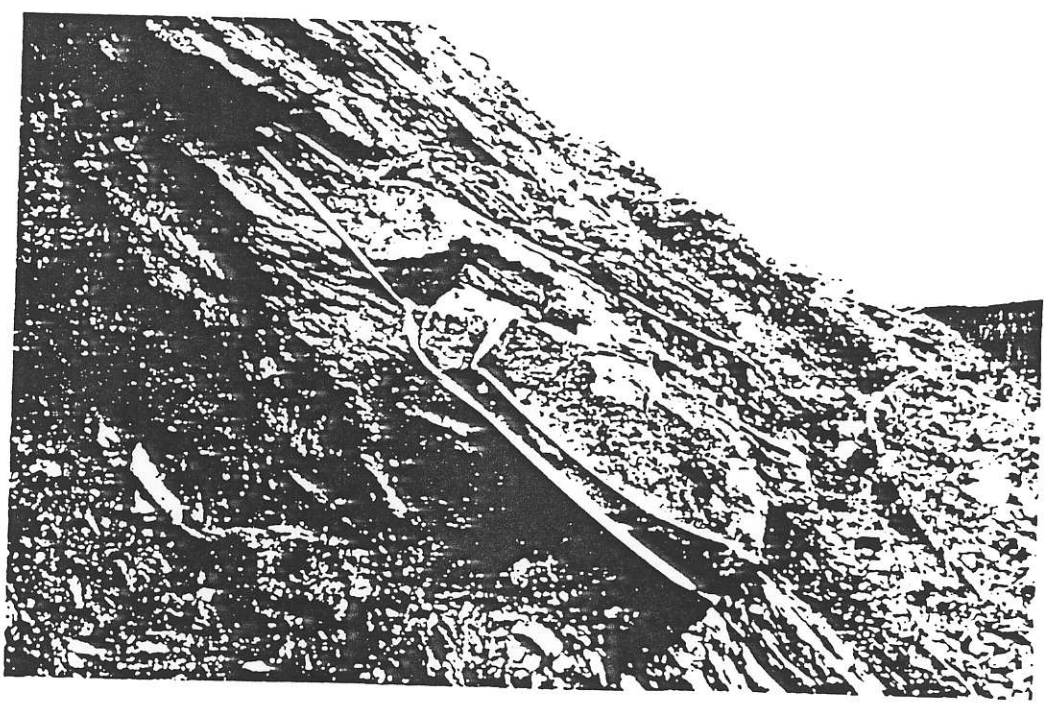
The sulphide deposits in the Eagle Bay Formation on the Adams Plateau occur both in sedimentary strata and in volcanics. The sulphides in sedimentary strata are Ag-Pb-Zn deposits (Lucky Coon, Spar, Mosquito King), while those in volcanics are usually Cu rich. The sulphide units in outcrop are 0.5 to 1.0 metre thick and consist of approximately 50% sulphides dominantly pyrite and pyrrhotite in a siliceous gangue. Typical grades are 10% Pb + Zn and 100gm/ton Ag over the 0.5-1.0 metre thickness with the best drill intersections being 4 metres of this grade. The host rock for the sulphides is usually the siliceous phyllite but deposits also occur in the limestone and greenschists.

The sulphide deposits have a regional strike continuity (Figure 4) but in outcrop trenohes and drill holes the sulphides are subbparallel to foliation and in detail are discontinuous along strike. Original bedding is difficult to define because of the penetrative foliation and the recrystallization and remobilization of the sulphides during metamorphism.

The association of sulphide units with particular stratigraphic levels suggests an original stratigraphic control to mineralization. Typically, sulphide deposits in sedimentary strata of Paleozoic age in western Canada are widespread, relatively thin sheets of interbedded sulphides and chemical sediments. Obviously there has been some distortion of this continuity by subsequent structural deformation.



A



B

On the scale of kilometres, the F_1 folds are defined by paired lithologic belts and by the abrupt disappearance of lithologies along strike. In the rare case of the Nikwikwaia Syncline, the structure is convincingly defined by a phyllitic quartzite bed.

Measurements of axial planes and fold axes are useful on the outcrop scale for defining the plunge of fold culminations and aiding in local correlations. When plotted on a sterogram, there is no preferred orientation because of subsequent deformation.

During the formation of the F_1 folds there was shearing along the limbs and axial planes producing rootless intrafolial folds and transposed layering parallel to the foliation. The disrupted folds within this layering causes the pinch and swell and lensoid aspect and lack of continuity along strike.

Folding (F_2, S_2)

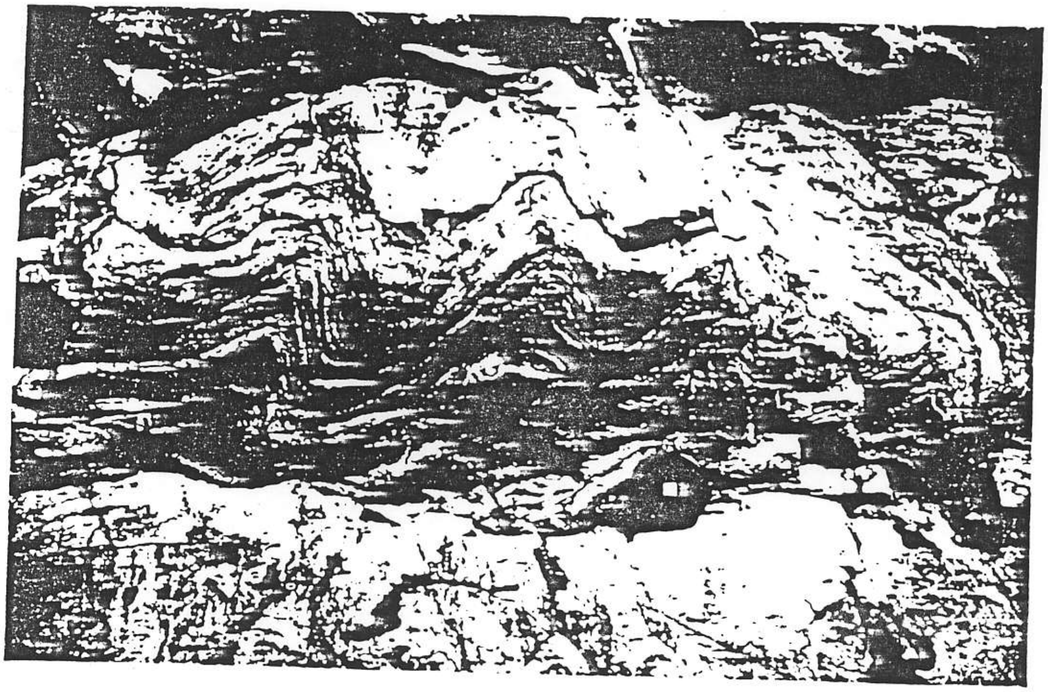
Second phase folds in which the bedding and foliation are re-folded, are open to tight, markedly disharmonic and may show vergence. They are usually best defined in phyllitic layers from 5 to 50cm thick with no structural disturbances above or below in the more siliceous layers (Figure 7a). Where the folds themselves are not obvious, there is usually a well-developed set of crenulations whose axial planes are parallel with S_2. S_2 cleavage parallel to F_2 fold axes is usually not well developed. The strike of F_2 axial planes in outcrop scale is dominantly between 240^o and 300^o and fold axes plunge both east and west (Figures 8 and 10).

On the scale of tens to hundreds of metres, F_2 folds are defined by warping of S_1 foliation, lithologic units or even F_1 axial planes. The lack of continuity of outcrop on the Adams Plateau makes mapping of this scale of folding uncertain.

Folding (F_3, S_3)

F_3 folds are open with nearly vertical north-south trending axial planes. They usually cause a gentle, large-scale warping of stratigraphic units as can be seen on the regional map (Figure 4). Similar folds can be mapped in limestone outcrops in a few areas. There seems to be little development of S_3 foliation but the fold axes are subparallel to major faults and there would appear to be a temporal connection.

Figure 7



A

B

EFFECT OF STRUCTURE ON SULPHIDES

F_1 Folds

In the Lucky Coon area (Figure 4) the sulphide unit is generally continuous for 2500m at a specific stratigraphic level but in detail the mineralization is thin and discontinuous and correlations are not clear. Outcrops and drill intersections of ore grade sulphides vary from 5cm to 4 metres thick, this upper limit being an attractive mining width. Much of this discontinuity can be explained by the behaviour of the sulphides in response to folding.

Thickening of a sulphide unit in the hinge zone of an isoclinal F_1 fold was observed in one of the open pits (Figure 6b). The axial plane is subparallel to foliation and the fold axis plunges southwest at 8°. The sulphide bed is 25cm thick on the limbs of the fold and 45cm thick at the crest.

This flow of sulphides in response to folding is suggested at many of the showings on the Adams Pleateau but it is usually impossible to quantify because of the lack of bedding definition. The F_1 structure affects the continuity of the sulphides but it also provides potential foci for thickening the sulphide zone to a mineable width.

It might be expected that a major concentration of sulphides would occur at the hinge zone of regional F_1 folds such as at the southwest end of the Nikwikwaia Syncline. There is at present no evidence for this because the sulphide bed does not seem to continue far enough along strike to the southwest to have been caught up in the folding. The hinge zones of major F_1 folds adjacent to sulphide showings would seem to be attractive targets for exploration at depth.

F_2 Folds

The best example of sulphides affected by east-west trending F_2 folds is at the SPAR showing (Figure 4) where an adit has been driven 10 metres into relatively massive sulphides. The structure on which the sulphides are concentratred is an upright, slightly asymmetrical fold whose axis plunges 25° at 240°. Sulphide mobilization is quantifiable in a minor fold just on the north side of the adit (Figure 7b) where the sulphide thickness at the crest is twice that on the limbs. This particular structure also shows thrust slippage along the fold limb and truncation of the sulphide bed. which way

If this mobilization of sulphides in F_2 folding occurred in larger scale F_2 structures, substantial thickening of sulphide bodies would be expected in the hinge areas of these structures.

$_3$ Folds

No thickening of the sulphides was seen associated with any F_3 folds. F_3 folding is open and would not be expected to cause mobilization. This folding is more significant in that it is associated with faults across which there is major offset of the sulphide bearing strata.

EXPLORATION TACTICS

F_1 Folding

Isoclinal folding of F_1 affects exploration on both the regional and detailed scale. On the assumption that there is a favourable stratigraphic horizon at which the sulphides occur, exploration needs to be concentrated on this unit. This is particularly significant in the Lucky Coon area where the favourable stratigraphic horizon can be projected from the known mineralization around the structure to the south and east (Figure 8). Exposure is poor in that area so geochemical and geophysical surveys were concentrated on this projection of the mineralized zone around to the underlying limb of the structure. Geochemical targets have now been defined and await trenching and drill testing.

The stratigraphic level of the sulphides in the Nikwikwaia Syncline can be projected across folding and faulting to the SPAR showing (Figure 4). From there the stratigraphic level can be followed across faults to the eastern half of the plateau where to date there are no known showings on the south limb of the syncline. Exploration should be directed to the area immediately north of the ɹartzite unit where mineralization similar to that at Mosquito King might occur.

On the detailed scale, as at the Lucky Coon (Figure 6b) it must be recognized that thicknessess and location of sulphides occurring on the surface cannot be simply projected downdip along the foliation. If the orientation of the F_1 fold axes can be measured then any thickness of sulphide beds encountered at surface or in drill holes can be projected along the bedding and down the plunge of the fold axis. The variation in thickness along strike and subsurface of the sulphide zone at Lucky Coon is probably largely caused by the F_1 folding on the northern limb of the syncline.

An attractive drill target would be the culmination of one of the moderate scale F_1 folds such as the overturned syncline mapped on the Mosquito King property (Figure 9) around the mineralization. Definition of the geometry of such folds would require a series of drill holes with detailed correlations. Single drill holes provide insufficient control to correlate stratigraphy and mineralization from surface to depth (Figure 10).

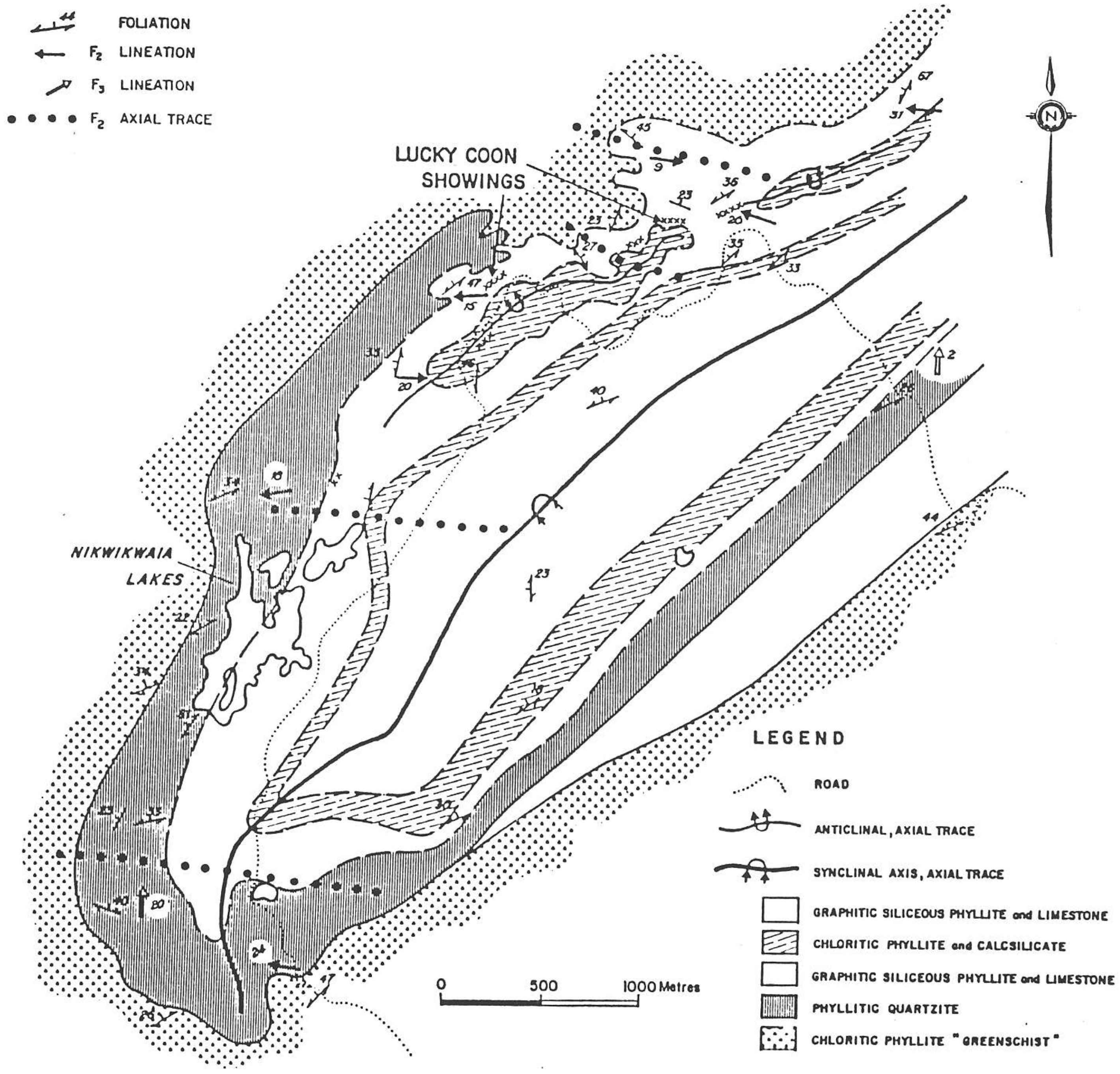
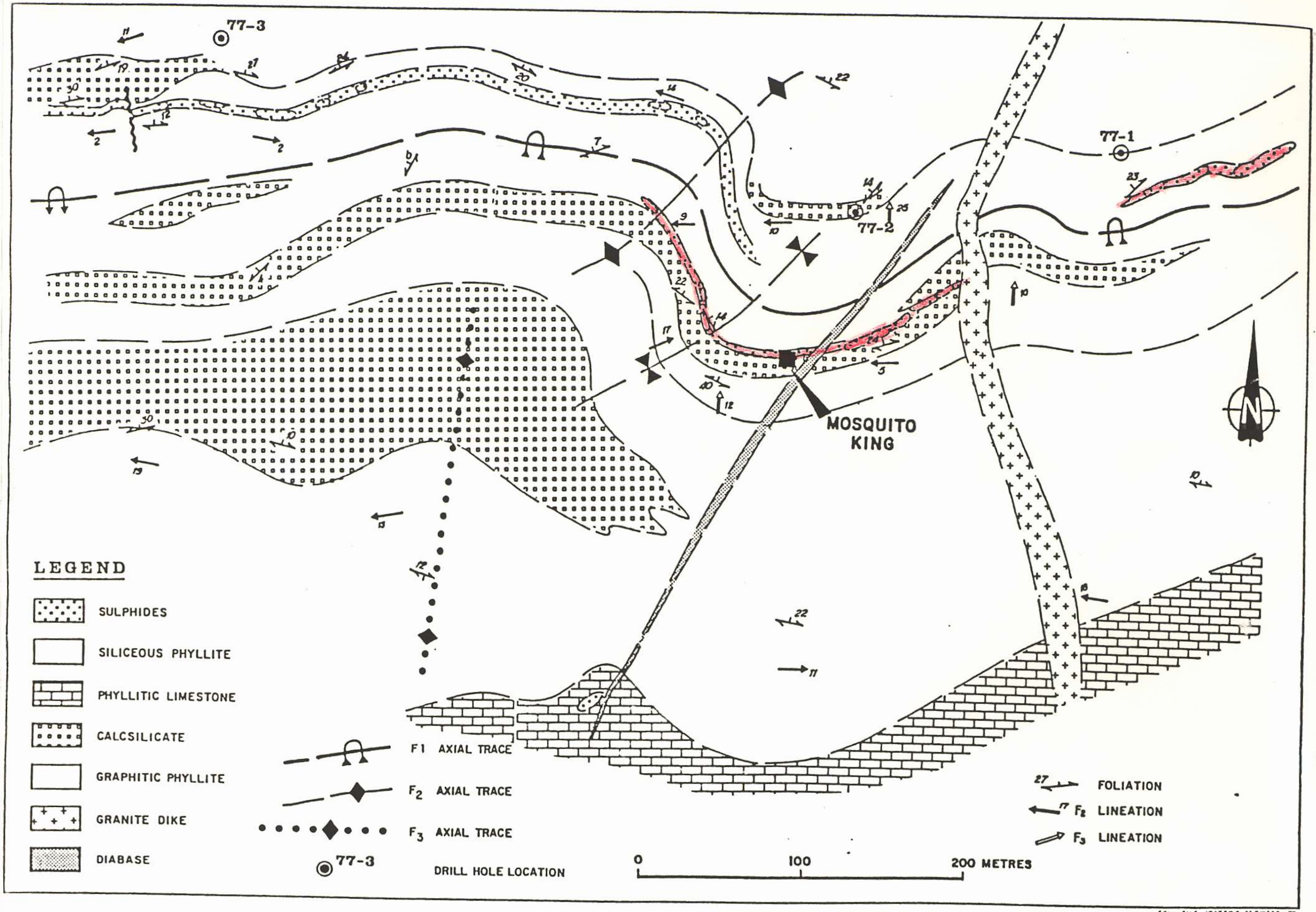

FOLIATION
F2 LINEATION
F3 LINEATION
F2 AXIAL TRACE
LUCKY COON SHOWINGS
NIKWIKWAIA LAKES
LEGEND
ROAD
ANTICLINAL, AXIAL TRACE
SYNCLINAL AXIS, AXIAL TRACE
GRAPHITIC SILICEOUS PHYLLITE and LIMESTONE
CHLORITIC PHYLLITE and CALCSILICATE
GRAPHITIC SILICEOUS PHYLLITE and LIMESTONE
PHYLLITIC QUARTZITE
CHLORITIC PHYLLITE "GREENSCHIST"
0 500 1000 Metres

Figure 8


77-3
77-1
77-2
MOSQUITO KING
N
LEGEND
SULPHIDES
SILICEOUS PHYLLITE
PHYLLITIC LIMESTONE
CALCSILICATE
GRAPHITIC PHYLLITE
GRANITE DIKE
DIABASE
F1 AXIAL TRACE
F2 AXIAL TRACE
F3 AXIAL TRACE
77-3 DRILL HOLE LOCATION
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100
200 METRES
27 FOLIATION
17 F2 LINEATION
F3 LINEATION

Figure 9

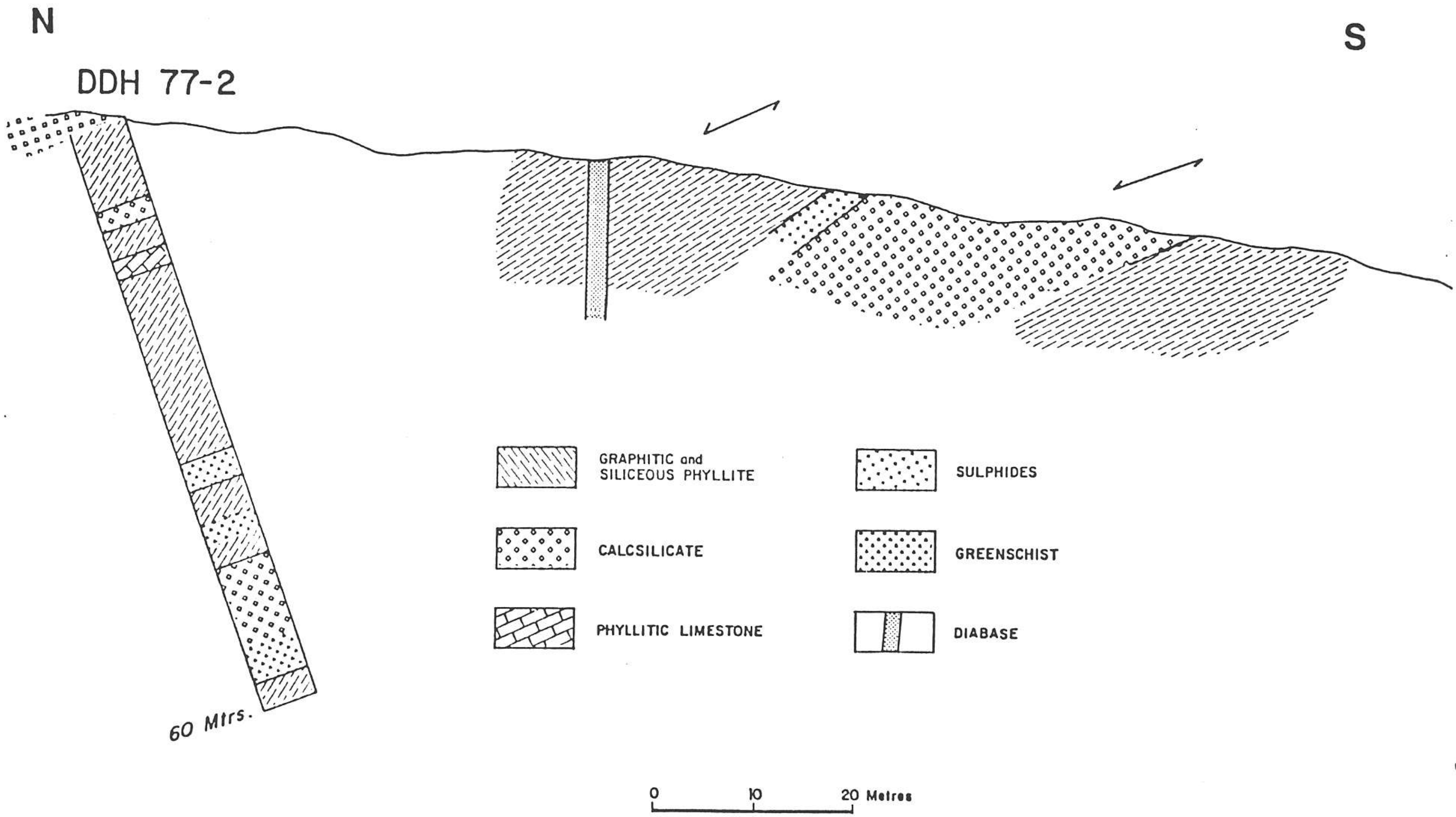
N
S
DDH 77-2
60 Mtrs.
GRAPHITIC and SILICEOUS PHYLLITE
CALCSILICATE
PHYLLITIC LIMESTONE
SULPHIDES
GREENSCHIST
DIABASE
0
10
20 Metres

Figure 10

F_2 Folding

For the moderate-sized deposit expected in this geological environment, F_2 folds with a wavelength of 0.5 - 1 kilometre would probably be the most significant in concentrating sulphides at fold culminations. An example of such folding was defined by detailed mapping around the Mosquito King main showing (Figure 9). There the lithologic units and the F_1 synclinal structure are folded into an anticline-syncline pair with fold axes trending 60^{o}-80^{o}. These trends are compatible with and are corroborated by orientations of small-scale F_2 folds and crenulations measured in outcrops in the vicinity. Locally, plunges are to the northeast and southwest but the northeast plunge seems dominant. Where the hinge zone of the F_1 fold occurs in the hinge area of the F_2 folds would appear to be a prime location for sulphide accumulation.

Accordingly, the next stage of exploration was to establish an Induced Polarization grid with measurement lines normal to the F_2 fold axes. The survey defined deeper (80 metres) anomalies which appeared to be response from sulphide bodies parallel to the fold axes. To date these anomalies have not been drill tested because of a lack of funding.

Shape of Target

If there has been significant sulphide mobilization during F_1 and F_2 folding, an originally tabular sulphide body would be a series of thick cylindrical pods connected by thin sheets and stringers. The pods would be economically attractive because of their mineability but it is likely that a number of such pods would be necessary to provide sufficient tonnage for a mine development.

An exploration and development program for numerous pod-shaped ore bodies requires very different techniques and planning from a program for a predictable tabular mass.

CONCLUSIONS

Surface showings and drill intersections of Ag-Pb-Zn sulphides on the Adams Plateau are generally of moderate grade (10% Pb + Zn, 100gm Ag/ton) over narrow widths with occasional ore grade and thickness intercepts. The sulphide zone is hosted in siliceous, limy and graphitic phyllite of Devonian-Mississippain age, and the showings appear to be stratigraphically oontrolled. To attain economically attractive deposits, the presently known thin sulphide depositional unit must be found thickened stratigraphically or structurally. This requires an ability to trace the stratigraphy on surface and to project the locations of structural thickening.

F_1 folding is the main factor determining the disposition of the stratigraphy, and a recognition of F_1 axes can point to covered areas where the sulphide zone should occur. Geochemical and geophysical programs can then be much more specifically positioned over the target areas.

The thickness of sulphide beds has been shown to respond to F_1 and F_2 folding. This response to structure seems to explain the discontinuous nature of the sulphide zones but also provides loci for a thickening of the mineralization to mineable widths. Detailed mapping of lithology and structure around showings provides a framework for projecting any thickening trends into the subsurface and for orienting subsequent geochemistry, geophysics and drilling. The 'rill targets will likely be cylindroidal pods rather than a tabular body and a number of these pods would be necessary to constitute an economic deposit.

ACKNOWLEDGEMENTS

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FIGURE CAPTIONS

Figure 1 Location Map

Figure 2 Adams Plateau in relation to the major tectonic elements of the Canadian Cordillera

Figure 3 Regional geological setting of the Adams Plateau. Detail area is shown in Figure 4

Figure 4 Adams Plateau geology showing major lithologic units and large scale structures. Foliation orientations are representative of many readings

Figure 5 Bedding in Eagle Bay Formation clastics

a. Rhythmic bedding in fine grained phyllite preserved in the hinge region of an F_1 fold.

b. Banded quartzite bed approximately 20cm thick in fine grained phyllite. Note high angle between bedding and F_1 cleavage.

Figure 6 F_1 folding

a. Tight, isoclinal folds in phyllitic limestone.

b. Sulphide unit (outlined by tape) in sericitic phyllite showing thickening of sulphides in the hinge zone of an F_1 fold.

Figure 7 F_2 folding

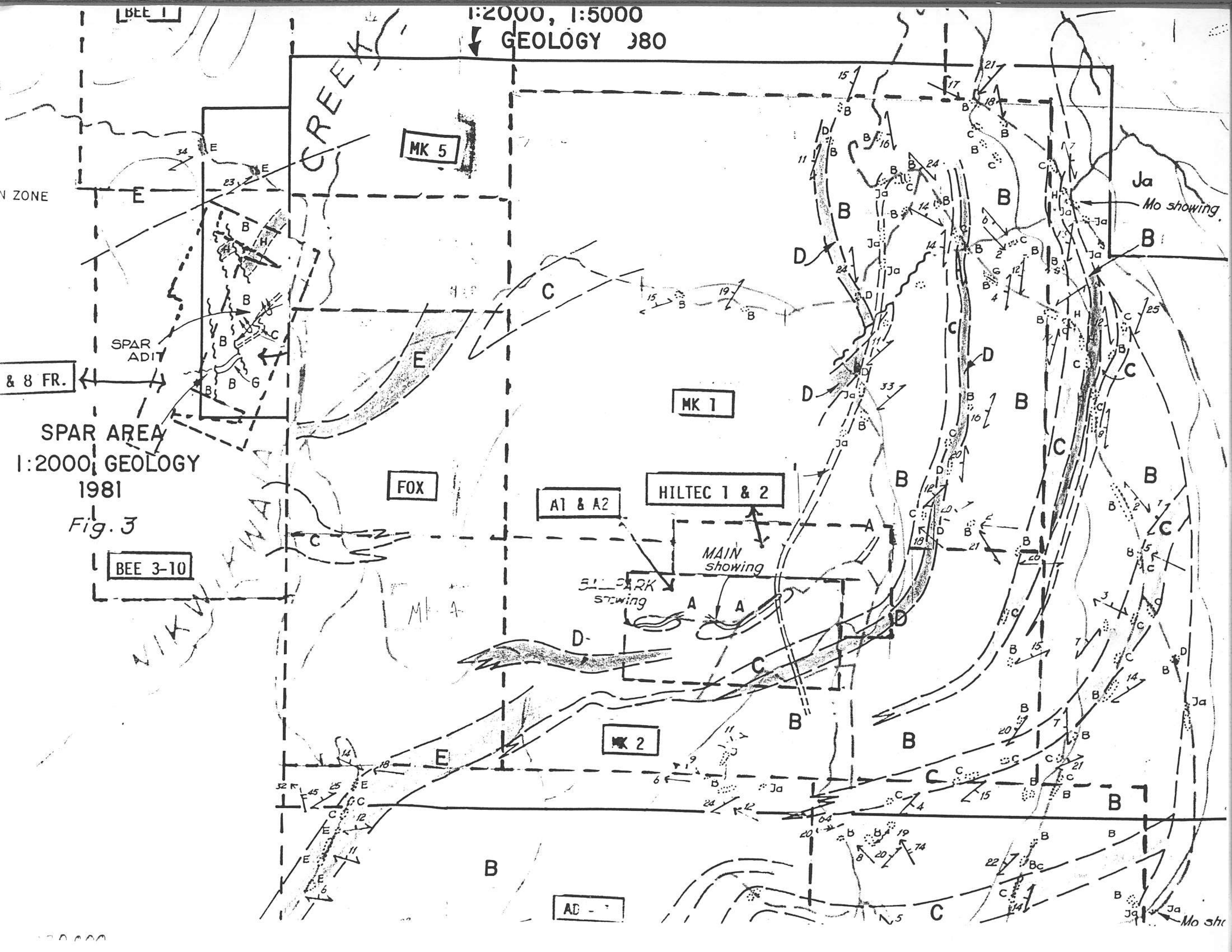
a. Asymmetric, relatively upright and open folds in calcilicate near the SPAR property

b. Sulphide bed thickening at the crest of a minor F_2 fold at the SPAR showing. The left limb of the fold is cut off by a thrust fault parallel to foliation.

Figure 8 Detailed geology of the Nikwikwaia Syncline showing the effcts of F_1 and F_2 folding.

Figure 9 Detailed geology of the Mosquito King area, Adams Plateau showing surface effects of F_1, F_2 and F_3 folding. Note location of diamond drill hole 77-2

Figure 10 Cross section connecting surface outcrops and down-plunge drill hole on the Mosquito King property. No obvious correlations are possible



1:2000, 1:5000
GEOLOGY 980
BEE 1
CREEK
MK 5
N ZONE
E
SPAR ADIT
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SPAR AREA
1:2000 GEOLOGY
1981
Fig. 3
BEE 3-10
FOX
MK 1
A1 & A2
HILTEC 1 & 2
MAIN showing
BALLPARK showing
MK 2
AD
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Mo showing
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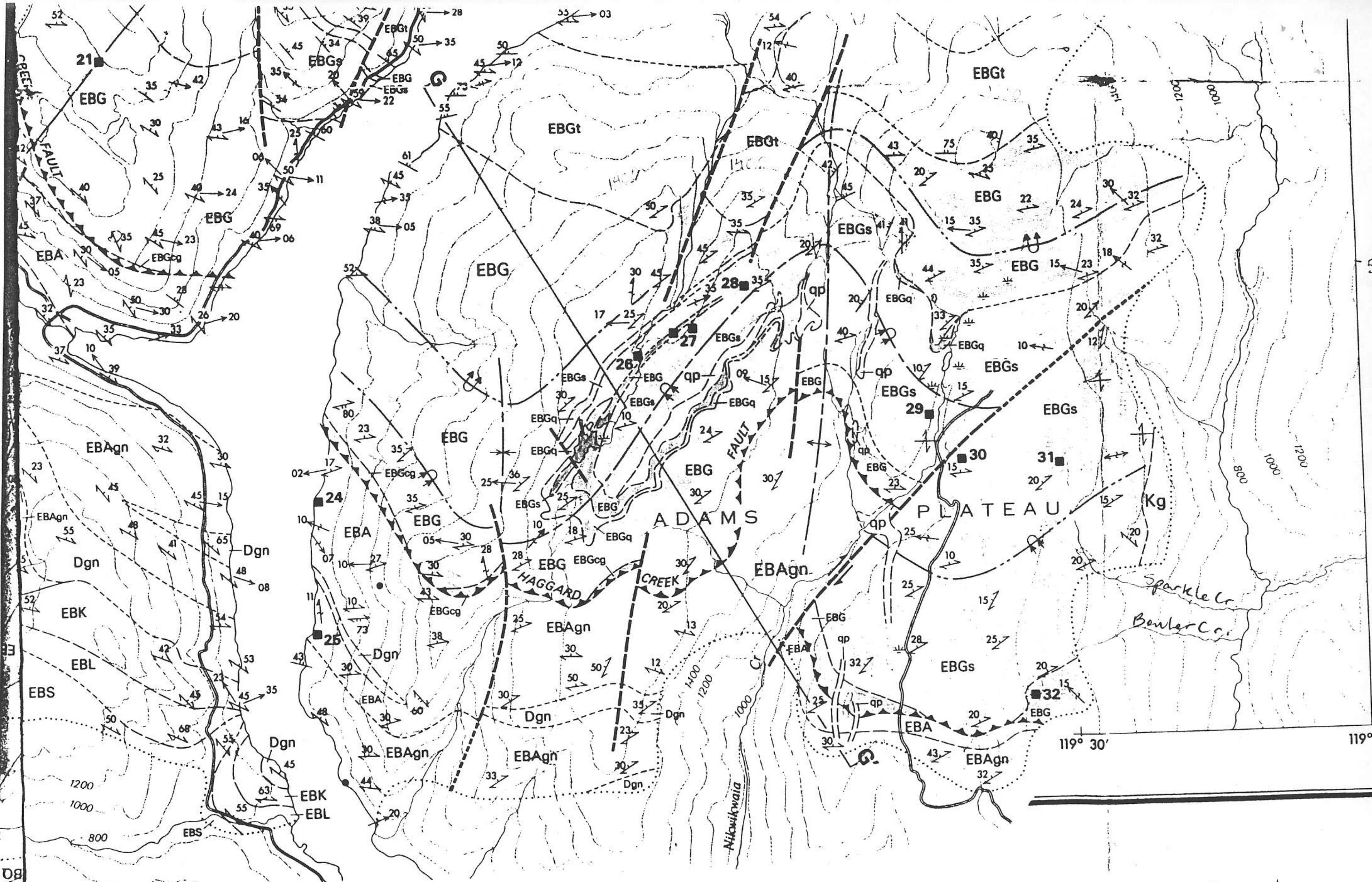

24 Beca (Tom)
25 Joe (Glen)
26 Elsie
27 Lucky Coon
28 King Tut
29 Spar
30 Pet
31 Mosquito King
32. BC (Cu5)