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EVALUATION OF EXPLORATION TARGETS

IN THE WHITEHORSE COPPER BELT, YUKON

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University of Western Ontario
London, Ontario

August 16, 1979

INTRODUCTION

Given a life expectancy of 2 - 3 years for the present operation it is necessary to evaluate the exploration potential of the Whitehorse Copper Belt in an effort to extend the mine life, or failing that, to be confident no major orebodies will be found once operations cease. Exploration to date has emphasised geophysical anomalies in geologically favourable areas and has delineated several small, near surface occurrences. Discovery of deeper (and necessarily larger) orebodies requires deep drilling based on geologic concepts of ore distribution. The method used here defines a series of general ore control parameters and then for specific target areas models the ore environment by comparison with known occurrences. The similarity between the model and the known occurrence and the availability of pre-existing information help determine exploration priorities.

ORE CONTROL PARAMETERS

The ore control parameters used to establish the working models fall in three main groups: a) Structural; b) Stratigraphic; c) Skarn Petrology.

a) Structural Parameters

The most distinctive characteristic of the Whitehorse Copper Belt is the development of mineralised skarn in carbonate and clastic rocks that occur as pendants within the margin of the Whitehorse batholith. The distribution of skarn assemblages and isotopic work suggest the pendant shape provides a restricted zone of circulation for ore-forming fluids and results in more intensive skarnification and mineralisation within the pendant as compared with conventional batholith/sediment contacts.

In general, massive skarn development is restricted to a zone within 300 feet of the batholith contact and consequently pendants that are narrow (say less than 800 feet wide), elongated and deep hold the best ore potential (c.f. Little Chief pendant). Shallow "U-shaped" pendants have restricted volume and hence more limited ore potential (c.f. Cowley Park main zone).

Non-pendant batholith/sediment contacts may also host orebodies. For example, a "V-shaped semi-pendant" bound on one side by the batholith and on the other by clastic sediments contains the War Eagle orebody. The Black Cub South orebody is in sheared limestone adjacent to the batholith margin.

In the area south of the Pass Lake occurrence there is a pendant formed by the convergence at depth of the Whitehorse and Mt. McIntyre batholiths. A similar structure may also exist west of the War Eagle Mine where the Whitehorse batholith and Haeckel Hill pluton converge. In general, the normal pendant is a more favourable target than "semi-pendants", "convergence pendants" or batholith/sediment contacts.

b) Stratigraphic Parameters

The Little Chief orebody is elongated parallel to, and occurs adjacent to the contact between skarnified carbonate and the clastic sediment unit generally referred to as the "quartzite". The contact itself is parallel to one margin of the Little Chief pendant. Petrographic and chemical investigations suggest the "quartzite" may be an important source of Cu and Fe in the deposits and consequently proximity to the quartzite contact is an important ore control.

Recent mapping of the carbonate rocks which host copper belt skarn and ore has identified several different carbonate facies that are part of carbonate reef complexes. A brief description of these facies is included as Appendix I. Mapping and projection of these facies into the pendants suggest that different types of skarn and ore are developed in different host rock facies. The majority of silicate skarns are developed within the dolomitic limestone of the forereef facies and in the adjacent underlying "quartzite" whereas the magnetite-serpentine skarns are developed within dolomite of the bank facies or the base of the forereef dolomitic limestone. The association of magnetite-rich skarn with dolomitic host rocks is well described in the skarn literature (see Zharikov, 1968, for a review) and is explained by the precipitation of Fe as magnetite in Mg-rich Ca-poor host rocks where there is insufficient Ca to precipitate Fe as Ca Fe silicates (e.g. iron rich garnet, clinopyroxene or amphibole). Location of dolomitic host rocks within the contact aureole of pendants is an important guide to magnetite-serpentine skarns which are the most important ore host in the copper belt.

c) Skarn Petrology

Typical silicate skarns in the copper belt contain small amounts of spectacular mineralisation (e.g. Copper King) or no mineralisation at all (e.g. Little Chief hangingwall). Mineable silicate skarns have either unusual mineral assemblages (wollastonite at War Eagle) or have mineralisation associated with vein and patch alteration cross-cutting the original silicate skarn (e.g. actinolite-chalcopyrite veins in diopside skarn at Arctic Chief or epidote-quartz-actinolite alteration of skarnified quartz-

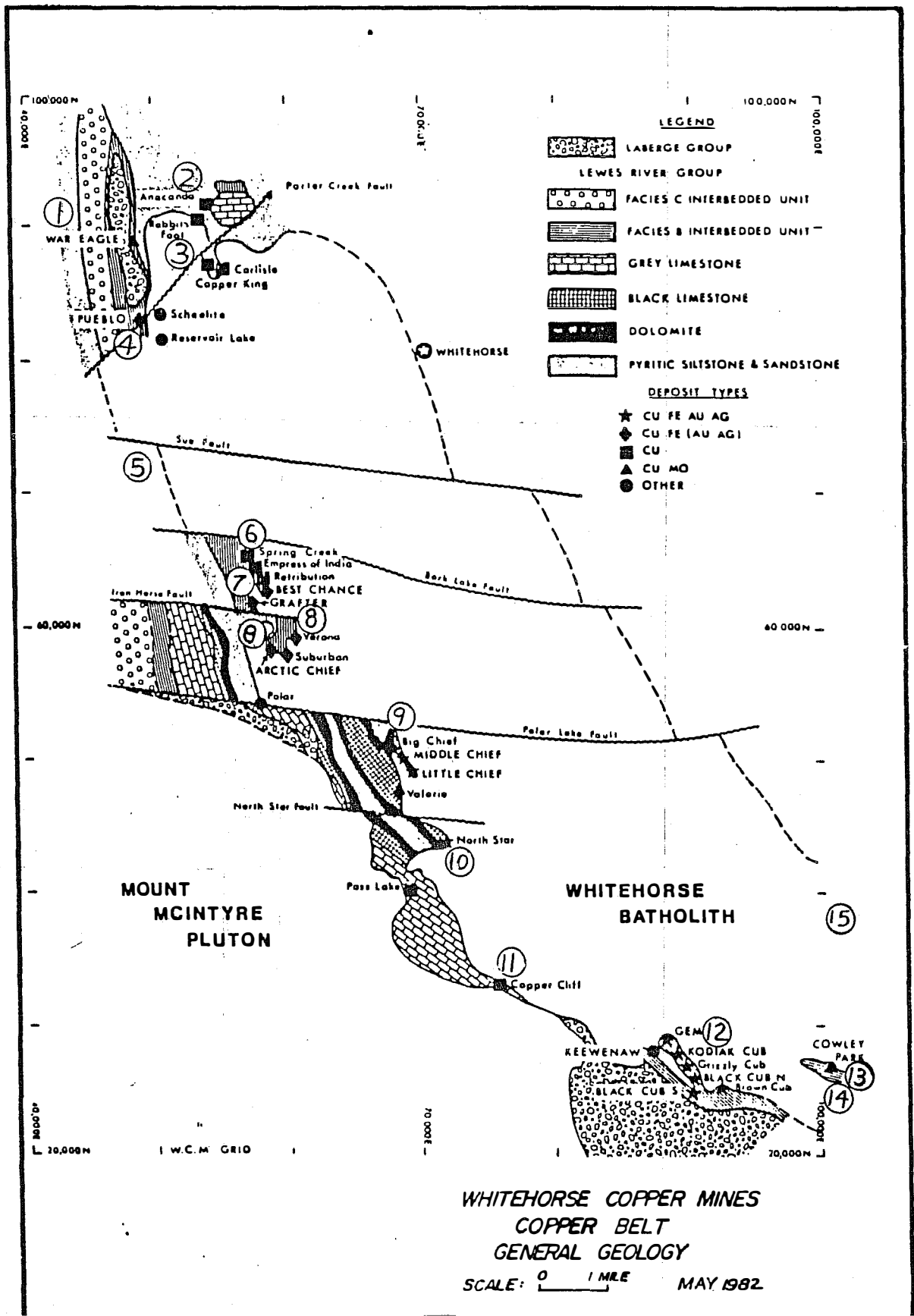
ite at Cowley Park). The extensive secondary alteration of silicate skarn is a good sign of mineralisation. Such alteration may also produce some magnetite-rich skarn at the silicate skarn/carbonate contact in the presence of dolomitic rocks (e.g. Arctic Chief). The distribution of minor metals also appears controlled by the composition of the host rocks. Silicate skarns developed, at least in part, from a quartzite host have the best molybdenum values (e.g. Cowley Park, War Eagle) whereas gold is concentrated in magnetite-serpentine skarns especially where the host rock is laminated dolomite of the bank facies (e.g. Little Chief).

WHITEHORSE COPPER MINES
SUMMARY OF
REMAINING EXPLORATION TARGET AREAS

*Passive - completion maps / assessment of quality of mapping
/ geol. regional map
(with thesis?)*

A. Hureau
May 1982

FIG 1



limestone outcropping on the east side of the highway. Drilling should be considered to check the limestone-quartzite intrusive contact, near the highway, 1200' north of the Fish Lake turnoff. Hole RF2 drilled by HBED in 1973 was stopped only a few feet past skarn in diorite.

No anomalous IP or mag results were obtained over the sediments-intrusive contact east of the highway and north of McIntyre Creek. Drilling would appear to be the only way to test this contact at depth.

3. Copper King - Carlisle

This large pendant contained several small lenses of high grade ore. Only two deep holes have been drilled to test the zones under the workings. A third hole between the Copper King & Carlisle workings should be considered. Any new holes drilled in this area should be checked for tungsten.

IP using north-south lines (strike of zone is east) done in 1964 used only a 200' separation, check lines using wider spreads should be done on N-S lines.

4. Pueblo-Gulch

Ref 1981 Budget

A narrow (15.6') good grade (2.81% Cu) intersection in PB 16, in 1981, north of the Pueblo mine has not been followed up.

The sediments-intrusive contact west and north of the Pueblo pendant has NOT been tested. The area is heavily overburden covered and should be considered if a workable geophysical method for detection of deeply buried, poorly conductive, deposits evolves.

5. Pueblo to Bork Lake

Ref. 1980 Budget # 3&4

1981 Budget # 6a & 6b

1982 Budget # 10

Results of the airborne survey, prospecting and extending the ground mag coverage to the west may help establish the intrusive-sediments contact. IP or possibly EM may detect mineralized zones near the contact.

6. Spring Creek

Hole B.C. 46 drilled under the Spring Creek workings intersected traces of copper at the limestone skarn contact. An 800' hole should be considered to test the contact deeper in the pendant. (see Spring Creek off section 577 E - NIM)

*Should have been drilled in 1962
with summer crew
(geol. mag, mag)*

*Must have tungsten
minerals found before?*

*← Check into
Bork Lake*

7. Grafter-Best Chance

Short good grade intersections obtained by HBED in 1972 viz:
6W, 20' @ 1.48% Cu 900' below surface.
9W, 20' @ 3.95% Cu 520' below surface & 19.5' @ 2.32% Cu 540'
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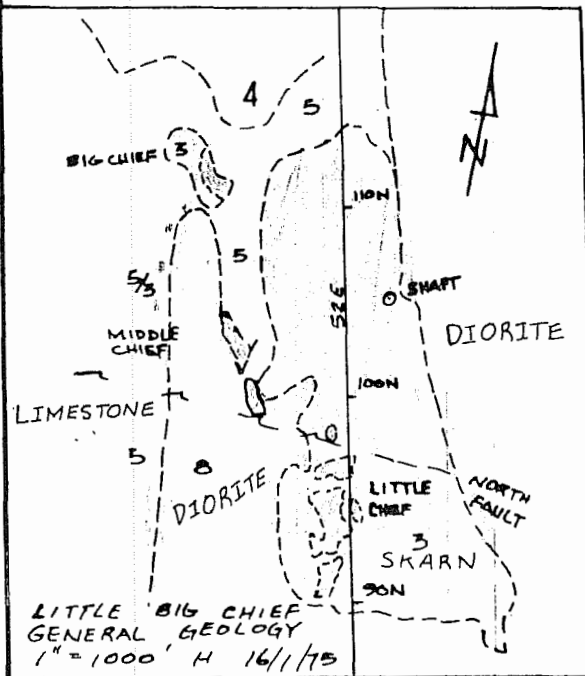
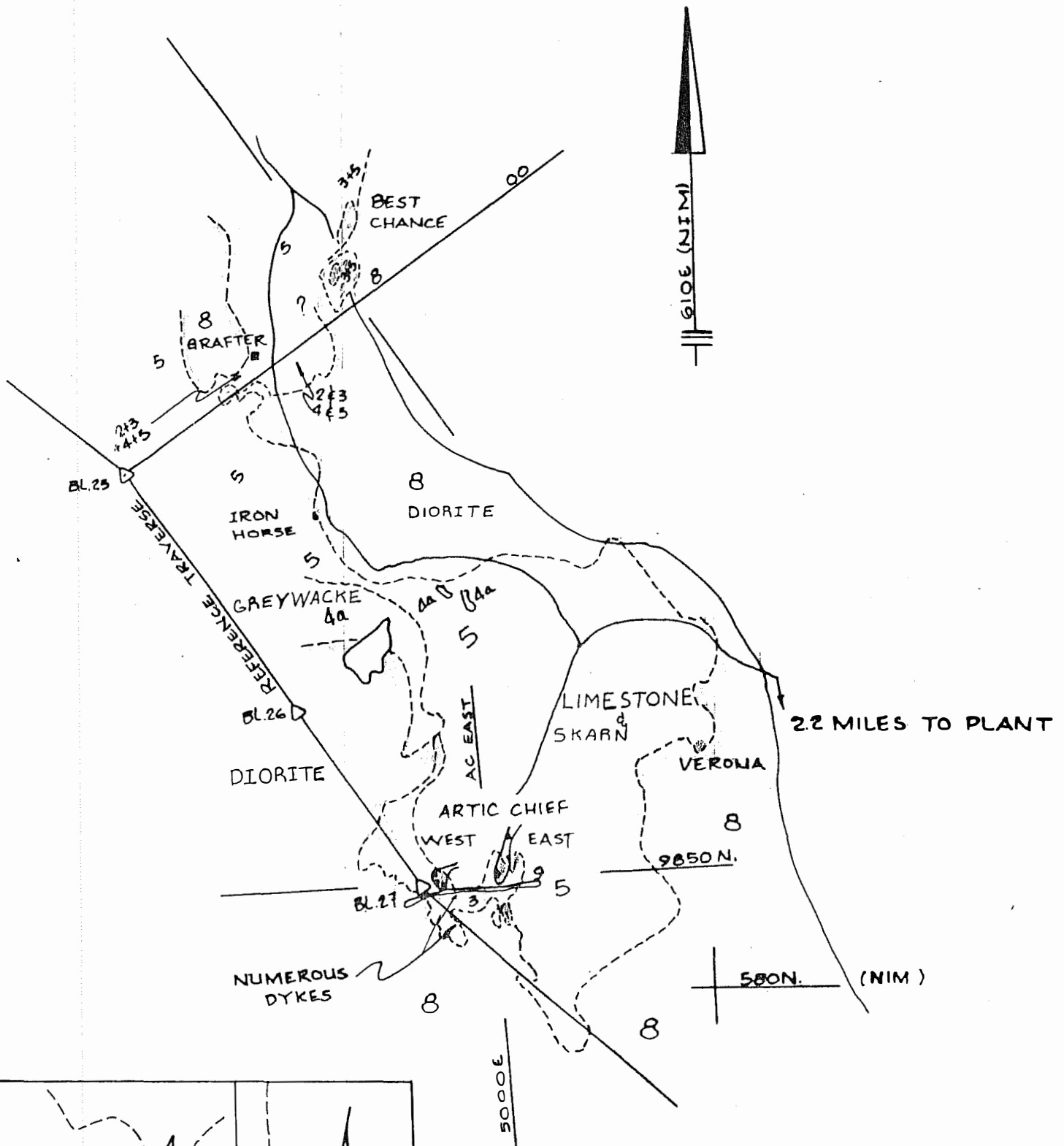
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of the Little Chief pendant (Fig. 2). Work to date has been
concentrated on mining of and exploring the small good grade
zones near the west contact of the pendant. Some potential
still exists for establishing small tonnage reserves north and
south of the pits. Hole AC 49 on sect. 102N could possibly be
deepened by reducing to AQ core, to determine whether mineralized
magnetite skarn continues below the intersections in AC 47 &
AC 48. Drilling to the south was hampered by the existence of
numerous irregular dykes which strike perpendicular to the
sections and were intersected in critical areas at very low angles
to the core. Any drilling program in the area should include
provision for directional wedging if dykes are intersected in
critical areas.

Four holes have been drilled to test the east contact of the
pendant. Results indicate that: (1) the intrusive contact is
steep and may be dipping to the east; (2) the footwall
quartzite steepens and may parallel the intrusive contact; (3)
dolomitic limestone and skarn extend to depths in excess of 2300'
below surface.

- A comparison with Little Chief geology (Fig. 3) suggests that the
depth at which the limestone quartzite contact is sufficiently
near the intrusive to be skarnified may, unfortunately, be in the
order of 2000'. However, the available strike and dip distances
of the contact, the nature of the Arctic Chief mineralization
(similar to Little Chief & with good gold content) and the
location, two miles from the plant could still make exploration
of this contact attractive.

Drilling to establish at depth the dip of the F.W. quartzite on
sect. 9850 N or 108 N is recommended as the first step in
evaluating the east side of the pendant. One of the two holes
suggested on sect. 9850 N should establish both the dip of the
quartzite limestone contact and that of the diorite to the east.
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900', (3) putting in a bypass wedge at 2040' and continuing to
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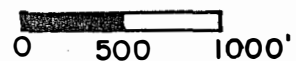
**WHITEHORSE COPPER MINES
ARCTIC CHIEF - BEST CHANCE
GENERAL GEOLOGY**

1" = 1000'

A.H.

MAY '82

SCALE :



8. Arctic Chief-Verona (continued)

Hole AC 58 passed through 50' of dioritized clastic sediments from bedrock before entering limestone. Much of the dioritized clastic sediments mapped in the Verona area may be underlain by limestone and skarn. A magnetic anomaly 250' long and 100' wide exists around the Verona trenches. The mag survey was done on lines near parallel to the zone. The survey should be redone using north-south lines. Banding in quartzite 400' SW of Verona strikes NE & dips 70° SE. A hole drilled to the north from approximately 105 N, 6575 E, is suggested to check the Verona mineralization which may extend to the southwest, under the clastic sediments. Drilling in this area may be helpful in establishing the dip of the intrusive contact on sect. 108 N.

do a
full log
(108 N)

9. North of Middle Chief

Consideration should be given to checking more thoroughly the Middle Chief contact north of the underground workings. Unfortunately, part of this contact is under the mill complex but some room does exist north and south of it.

A 1000' hole drilled at -55°W from 5615 E on section 110 N or 10950 N is recommended.

10. North Star-Valerie

(see Summary Report & Recommendations A.H. May '82).

11. Copper Cliff

Ref. 1981 budget proposal.

The Copper Cliff pendant has not been tested by drilling. A detailed mag survey and mapping, possibly to be followed by an IP survey and drilling, should be considered.

full log

12. Gem-Brown Cub-Cowley

There appears to be little chance of improving reserves of known zones in this area. If Gem should become economic the smaller zones (Black Cub North-Kodiak Cub) should be reassessed.

The limestone-quartzite intrusive contact east of Black Cub south in the Brown Cub area is weakly mineralized. No geophysical targets are known along this buried contact which extends for two miles east to Cowley Creek. IP has delineated the limestone (graphitic) - intrusive contact and small weakly mineralized skarn zones have been drilled 4000' south of the Cowley Park main zone. Copper bearing skarn zones whose IP response has been masked by that of graphitic limestone could exist along this contact. If a geophysical method evolves which could distinguish these deposits, its application should be considered in this area.

13. Cowley Park Main Zone

Additional drilling on this zone would be for pit definition if the zone became economic with possible small increases in reserves.

14. Cowley Park South
Ref. 1982 Budget Proposal

Reserves on this zone could probably be improved by drilling along strike to the east and west. Orientation EM surveys should be done and if correlation with known zones is present, the surveys should be extended to the east to help delimit the mineralization.



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Ref. 1981 Budget Proposal

The mineralization intersected by Canex Placer on Lewes River Mines ground should be considered for follow up work, if prices improve and ground adjacent to the four claims currently held is released from the pipeline staking freeze.



WHITEHORSE COPPER MINES
SUMMARY OF
REMAINING EXPLORATION TARGET AREAS

*Passive - completion maps of Dept. of Geology
assessment of quality of mapping
(with Davis?)*

A. Hureau
May 1982

Introduction

The following areas on the Copper Belt should be considered, if economic conditions improve and the development of small to medium sized copper deposits becomes attractive.

Target areas are listed from north to south and not in order of preference; North Star, Arctic Chief, and Cowley Park are considered to offer the best potential. Some areas, e.g. north of War Eagle, would only be considered if high prices allowed for the mining of much lower grade than is currently economic. Zones which have good grade, low tonnage potential, e.g. north of Arctic Chief west and Cowley Park south may be considered if production from these zones could supplement production from larger mines.

Results of the airborne Mag-E.M. survey '81 have not yet been studied in detail. No anomalies were plotted on preliminary sheets over the North Star and Arctic Chief pendants. An anomaly was detected near the east end of the Cowley Park main zone. Data from the survey should be reviewed when available, in conjunction with geological and ground geophysical information.

Areas of the Belt should be re-evaluated when any geophysical breakthrough or refinement of existing methods make heavily overburden covered areas or areas which may contain deeply buried blind deposits more amenable to exploration. Refinement of seismic methods may make these techniques applicable to help define stratigraphic contacts at depth.

The further development of stratigraphic models and recognition of different carbonate facies in areas where they have been recrystallized, near the intrusive, may help to more accurately predict targets at depth. The existence of limestone, skarn and mineralization under diorite and dioritized quartzite at North Star, Grafton, and the south end of Little Chief should caution against rash projections of intrusive contacts from surface which make zones appear too small to be attractive.

Geological controls for ore deposition are summarized by G. Morrison in the 1980 budget proposal. The paper is attached as appendix 1.

1. War Eagle Area

Ref. Exploration Budget Proposal 1980

- a) Two holes proposed for under the War Eagle pit in 1980 were not drilled. Funds were diverted to areas considered to be more attractive. In addition mineralization on the east side of the zone (53 E, sect 77 N elev 2600') has not been followed down dip and to the south.

b) North of Pit

Low grade mineralization on sect 103 N (386' @ 0.31% Cu) could be tested up and down dip.

2. Rabbits Foot Canyon, Anaconda, Rabbits Foot, Ruby

Ref. 1981 Budget & Summary & Proposal G. Morrison & A. Hureau Sept. '80.

The area should be reassessed. A detailed mag survey around

Handwritten notes:
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fall 82
(d-92)

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WHITEHORSE COPPER MINES

NORTH STAR AREA

SUMMARY REPORT & RECOMMENDATIONS

A. Hureau
May, 1982

in the mineralization is comparable to that of the Little - Middle Chief zones.

The mineralization is erratic, being partly controlled by proximity to the intrusive contact which is irregular and variably gradational. Twenty diamond drill holes with an aggregate footage of 33,000' have been drilled on the property. No mineable reserves have been established in the area which should be considered as an exploration target. A figure of 800,000 tons at 1.5% copper is indicated for the footwall zone from drilling on sections 32 S and 36 S. High grade mineralization (48' @ 5% Cu) in silicate skarn, two hundred feet above the footwall contact may follow the contact of a diorite apophysis intersected 400' west.

A pulse E.M. survey using a Geonics E.M. 37 unit indicated a conductive zone along the north contact of the pendant for a distance of 3600'. Five holes drilled to test the indicated conductive zone have failed to intersect any mineralized zones or explain the survey results adequately.

Approximately \$1 million has been spent on the property to April, 1982 when the 1982 program was cancelled due to economic restrictions and the planned early shutdown of the mine.

The area is considered by the writer to offer excellent potential for the existence of ore zones which could be accessible from the Little Chief underground workings. Mineralization has been intersected over a distance of 2000' and a favourable contact may exist at depth for a distance of 10,000' around the pendant.

Recommendations

The value of the North Star area as an exploration target is critically dependent on the availability of the Little Chief underground workings and the Whitehorse Copper Mineplant facilities. Funds to explore the area adequately are unlikely to be available from W.C.M. or H.B.E.D. in the near future. It is therefore recommended that:

1. A joint venture partner be sought to continue the exploration program on the North Star property with W.C.M. remaining the operator if a mineable ore deposit is found. An interest of 40% for an expenditure of \$1 million is suggested. A commitment to drill a minimum of 15,000' within one year is recommended; this could be waived if early results justified driving out to the area from Little Chief underground workings.
2. If the foregoing recommendation is not consummated and H.B.E.D. retains the property, it is recommended that, if funds became available, exploration of the area be continued.
 - a) An orientation survey using borehole pulse E.M. should be done to determine whether zones known to exist could be detected by the survey of barren holes in the area (e.g. a survey of NS 18 to detect zones intersected in NS 15). If the orientation survey is successful, it should be extended to other areas, and followed up by drilling.
 - b) Drilling should be continued:
 1. to determine the limit of the pendant and mineralization to the south east. A preliminary hole at 2E drilled west @ -70°, 1800' is suggested on section 38 50 S, 40 S, or 42 S.
 2. to follow the high grade mineralization in NS 15 to the north and west. A vertical hole at 6W on 32 S or 34 S is suggested to a depth of 1600'.

north, the zone of facies change from carbonate to clastic sediment facies, near the intrusive is an attractive target. Such a zone probably exists along the Valerie contact. Check mapping, detailed ground mag and short drill holes are recommended to establish the attitude of the top of the limestone reef before deep drilling is attempted. Similar work is suggested west and southwest of NS 19 where a similar environment may occur.

- c) Dr. Gregg Morrison (P.H.D. Whitehorse Copper Belt) whose work contributed a great deal to the understanding of the setting of the deposits, will be working in Alaska during the summer and will be visiting Whitehorse. His services should be solicited to review all data and to suggest a model for the reef topography north and south of the pendant.
- d) Remnants of the carbonate and clastic sediment sequence may exist in the diorite between the south end of Little Chief and the North Star pendant. If difficulties with correlation of pulse EM response with the location of known conductive zones can be resolved, it is recommended that this area be covered by a Deep E.M. survey.

Introduction

Reinterpretation of geological and geophysical data in the North Star area in 1975, remapping (R. Reid), magnetic surveys and drilling of a broad low intensity I.P. anomaly led to the discovery of a large, nearly completely buried, flat lying limestone reef. This carbonate unit was extensively skarnified, near its contact with diorite of the Whitehorse Batholith, at the upper contact with overlying dioritized clastic sediments and at the footwall contact with underlying metasediments. Copper mineralization has been found in each of these skarn zones, with that near the shallow dipping footwall contact near the intrusive, at depths from 1400' to 1800', being most attractive.

The area was considered attractive because of, the similarity of the skarn zones to those of Little Chief, the size of the pendant and its proximity to the Little Chief workings and the W.C.M. plant. Only five holes were drilled in the area from 1975 to 1980 due to budget restrictions. In 1980, in hole NS 8, forty feet of massive magnetite with traces of copper mineralization was intersected at a depth of 1400', followed by 113' of silicate skarn which graded 0.52% copper.

A pulse E.M. survey using a Geonics E.M. 37 unit was completed by Geophysicon Ltd (Calgary) in 1981 using both a standard loop configuration and a mise a la masse system in which an electrode was located in the conductive magnetite intersected in NS 8. Five holes drilled to test an indicated conductive zone, extending for 3600' along the north contact of the pendant, failed to explain the results adequately.

Drilling southeast of NS 8 in late 1981 intersected good to high grade copper mineralization in intersection lengths of up to 48' and indicated true widths of up to 40'. Mineralization has been intersected over a horizontal distance of 2000' and has not been cut off along strike. The drilling program was cancelled in March 1982 due to economic restrictions and a planned early shutdown for the mine.

Work in the area has been hampered by the depth to the most favourable contact ($\pm 1500'$), the irregularity of the intrusive contact and the restriction of "ore" grade widths, to within a few hundred feet of the intrusive.

to the north and west. A 10' intersection at 3.34% Cu on section 32 S in NS 14 probably correlates with that in NS 15. Borehole pulse E.M. may be of some assistance in delineating this zone.

2. Footwall Zone

The footwall zone intersected on 32 S and 36 S is located at the base of the limestone at the contact with underlying clastic sediments. This zone only exists where this contact is within three or four hundred feet of the intrusive contact. Mineralization in this flat to shallow dipping zone is identical to that of Little Chief consisting of chalcopyrite, bornite and valleriite in a magnetite serpentine phlogopite skarn. The grade and thickness of this zone can change very quickly grading from a barren weakly skarnified contact towards the intrusive. On section 36 S the zone changes from 10' @ 0.98% to 47' at 1.53% in a distance of 160' with the grade of the mineralization in the latter intersection being 2%, but including an 11' dyke.

This zone can not be considered to be cut off by drilling on sections 70 600 E and 71 400 E. Holes 19 and 20 probably intersected the footwall contact too far from the intrusive while hole NS 11 on section 71 400 E did intersect weakly mineralized magnetite skarn which may improve in thickness and grade towards the intrusive contact. A hole layed out to intersect the zone a few hundred feet closer to the contact would determine whether ore grade mineralization does extend to this area. While the zone may generally be in the order of 1000 - 2000 tons/horizontal foot, the potential strike length and the likely existence of irregularities in the intrusive contact which could be expected to yield better mineralized zones, make it attractive.

The footwall zone may also extend to the southeast of section 38+50 S. Generally the grade of mineralization has improved in this direction. The southeast limb of the North Star pendant is interpreted to be 600' wide on 38 50 S and could reasonably be expected to extend several hundred feet southeast. There is a suggestion of steepening of the upper contact from banding in the core and good grade mineralization intersected in NS 5 near the upper limestone contact. If the attitude of the footwall were to steepen or the limestone reef grade out in this direction conditions would exist for more pervasive skarnification and ore deposition.

Hangingwall Zones

Narrow, widespread, erratic mineralization has been intersected at or near the upper skarn contact with the dioritized clastic sediments. These intersections were generally in the order of a few feet but do suggest that where the upper and lower contacts converge near the intrusive contact would be an attractive locus for ore deposition.

Other Considerations

The Craigmont model of G. Morrison (P.H.D. Thesis 1981) located the Craigmont underground ore zone at the facies change from reef limestone to clastic sediments. The North Star reef is shown to be grading out to the East on section 32 S and 28 S changing from 1500' thickness (NS 19 - 20) to 900' (NS 9 & 11). However, it was still 900' thick where intruded by the Whitehorse Batholith.

The diorite between the North Star Pendant and Little Chief may contain remnants of limestone and clastic sediments at depth. Some of the "diorite" in this area may be equivalent to the "dioritized" clastic sediments overlying the limestone reef. If confidence in interpretation and correlation of "Deep E.M." response to location of known conductive zones can be established, this area along with the contacts north and south of the pendant should be surveyed.

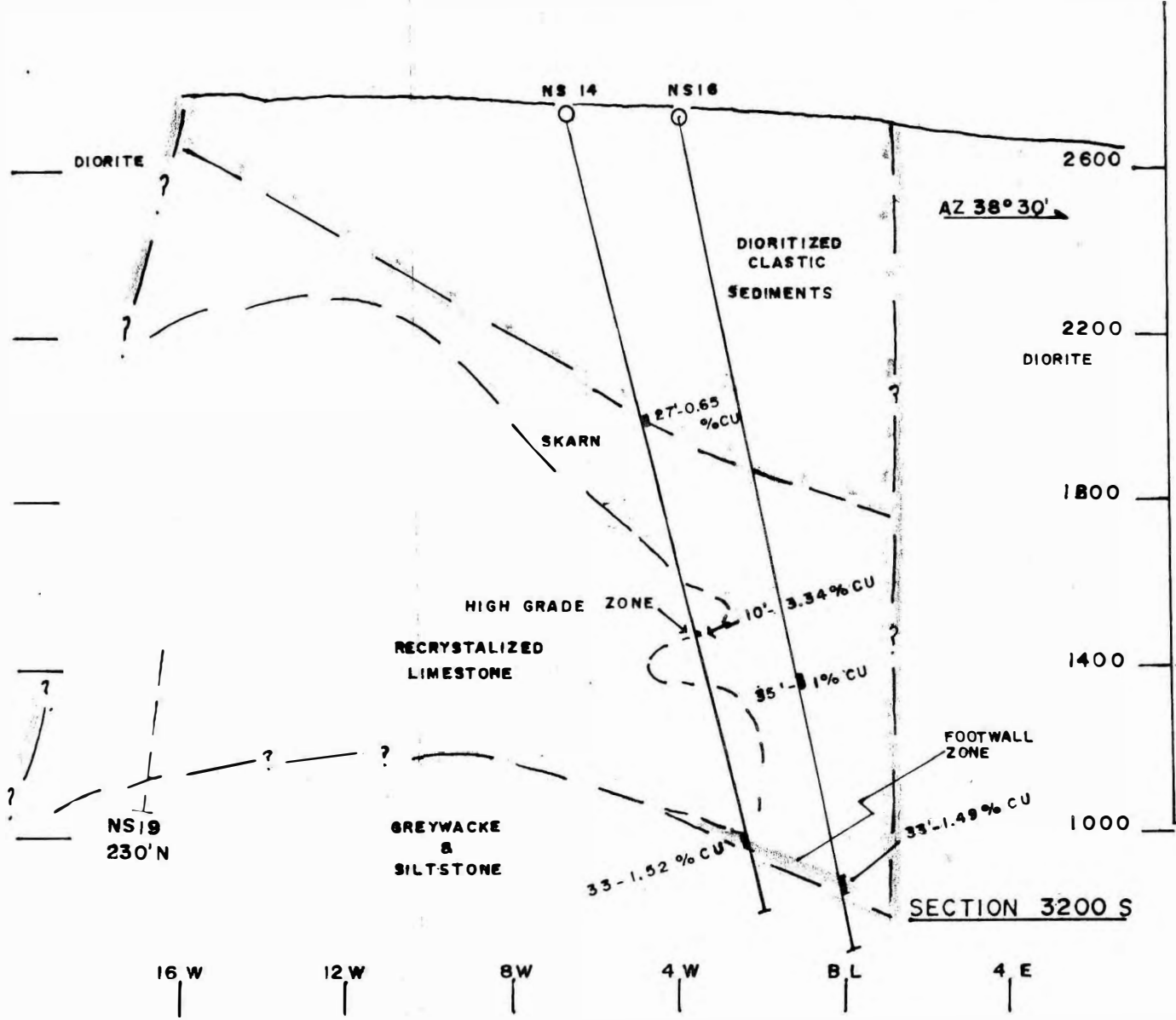
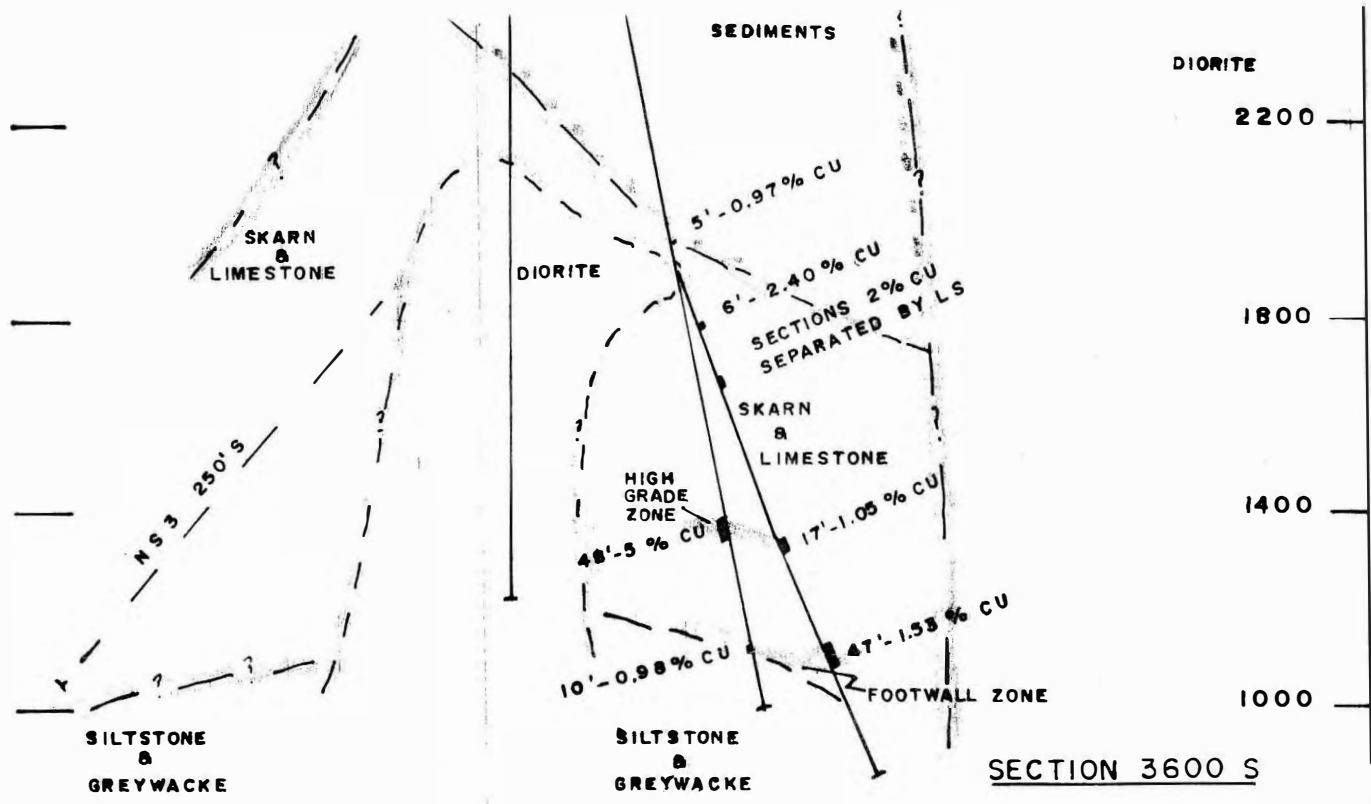
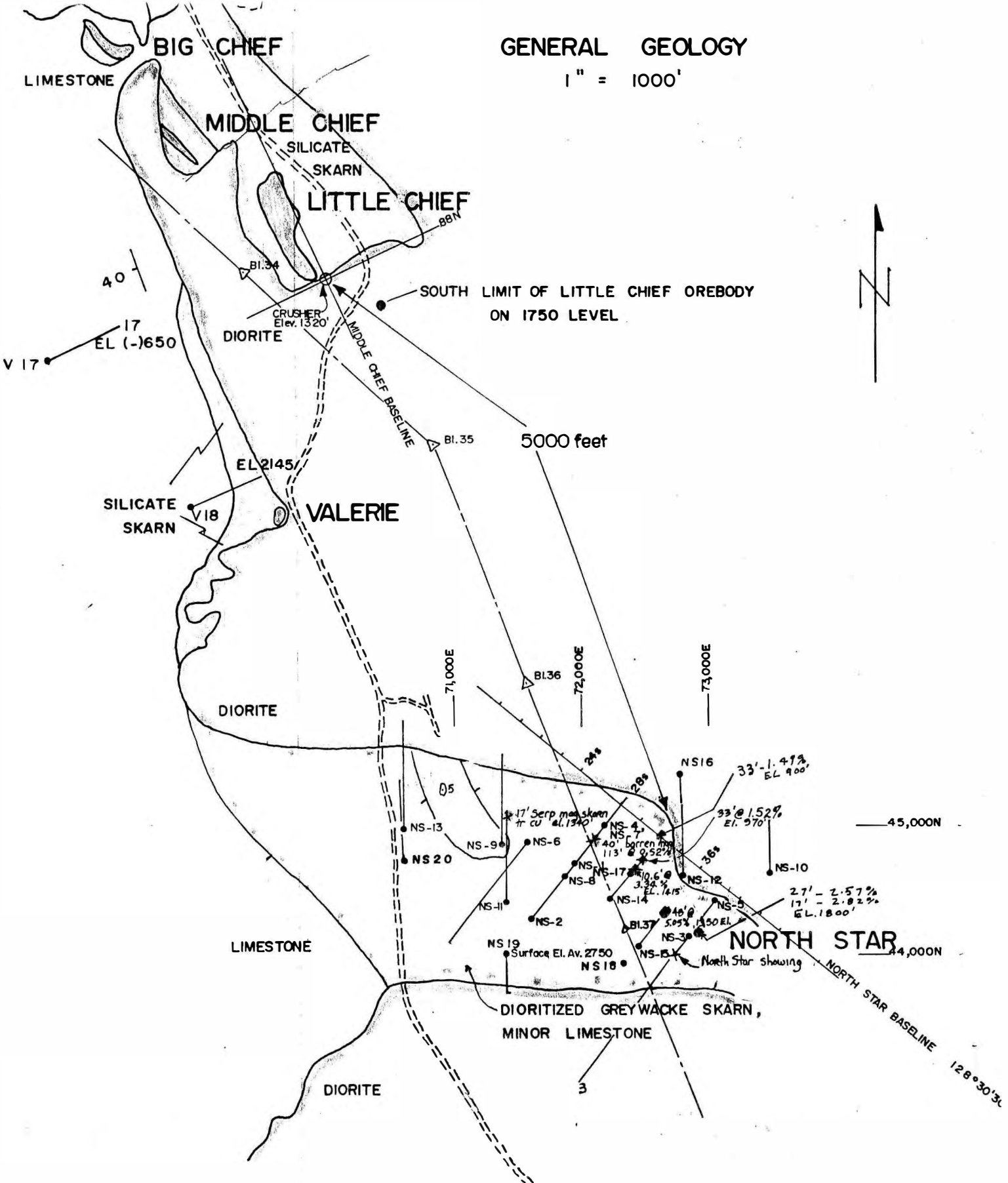


FIG. 2
 NORTH STAR
 SCHEMATIC SECTIONS
 1" = 400' A.H. MAY 1982

GENERAL GEOLOGY

1" = 1000'



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DIAGRAM
to illustrate
NORTH STAR DRILL PROGRAM

Scale: 1" ≈ 1000'

RBC - July 23, 1980

