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Preliminary Report on Geological Control to
Ore Distribution in the Whitehorse Copper Belt,
Yukon Territory

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no appendices

SUMMARY AND RECOMMENDATIONS

The Whitehorse copper belt has traditionally been described as skarn-type occurrences developed in limestone by metasomatizing fluids derived and emanating from an adjacent batholith. Our preliminary examination of these and similar occurrences elsewhere suggests that the common denominator among the deposits is not necessarily a pluton of particular composition and form but rather the stratigraphic section within which the deposits are stratabound. This section is relatively thin bedded dolomitic, bioclastic and stromatolitic limestone in a predominately volcanic terrain. The carbonate rocks are comparable to present day intertidal evaporities which prograde algal mats and which in turn are succeeded by continental clastic rocks. The buried algal mat decays and becomes saturated with hydrogen sulphide. It is suggested that water rising through the volcanic and clastic rocks to the evaporite surface may leach small amounts of metal which may in turn be deposited in the reducing environment of rotting algae. Such primary concentration of metal may later be reconstituted by metamorphism accompanying intrusion in the waning stages of volcanism and uplift.

Our recommendations are as follows:

1. Petrography of the layered rocks should be continued in an examination of the reasonableness of the above suggestion.
2. If the importance of evaporite-type carbonate

rocks is substantiated for the distribution of copper deposits in the Whitehorse copper belt then the paleogeography of the Upper Triassic shoreline should be mapped if possible.

3. Detailed mineralogy of the skarn assemblages should be determined to study the effects of metamorphism on metal distribution.

4. Radiometric age determinations should be completed on the plutonic bodies of the belt to study their relationship to the volcanic rocks, the nature of the total igneous event, and its contribution to metal distribution.

5. Recommendations 1 through 5 can be completed, along with a field check of some sections by the end of this summer. This will provide definition of the problem for application to Indian and Northern Affairs for a full season in the field in 1975.

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INTRODUCTION

1.

The Whitehorse copper belt, Yukon Territory, is 28 copper occurrences along 12 miles of intrusive contact between a batholith of quartz diorite and a layered sequence of andesite, greywacke, argillite, conglomerate, and limestone defined as the Lewes River Group of Upper Triassic age (Wheeler 1961). The batholith has been mapped as part of the Coast Range Intrusions of Cretaceous age. Copper occurs as chalcopyrite, bornite and chalcocite in calc-silicate and magnetite-bearing skarn. Mineralogy and distribution of occurrences suggest localization within particular limestone strata in contact with the batholith. Whitehorse Copper Mines Ltd. hold the known occurrences and operate the Little Chief Mine, central to the belt.

NO!?

This report consolidates 1973 field and laboratory study of geological controls to copper deposition in the Whitehorse copper belt. Work was done under research agreement with the Department of Indian and Northern Affairs and the first season's objective was a preliminary examination of the layered rocks stratigraphically enclosing the copper occurrences, the attendant pluton and other geologic variables affecting metal distribution and of possible significance to exploration. We have drawn heavily on past work particularly that of J.O. Wheeler (1961), the staffs of Whitehorse Copper Mines Ltd. and of D.B. Craig, Resident geologist, Indian and Northern Affairs. C.G. Winder of the Department of Geology, University of Western Ontario helped with petrography of the carbonate rocks and W.A. Marchant provided interpretations of the magnetic expression of the

The Whitehorse copper belt is 3 miles west of the City of Whitehorse and the Alaska Highway (figure 1). It is accessible by road from MacRae to offices and plant site of Whitehorse Copper Mines Ltd. in the centre of the Belt, and by the Fish Lake road which leaves the Alaska Highway 3 miles north of Whitehorse, and by a mine haulage road which follows the length of the belt from the War Eagle pit in the north to the Black and Tan Cub occurrence in the south. Rocks of the Lewes River group beyond the confines of the belt can be reached in the north part of the map area by the road from the Alaska Highway 4 miles south of Takhini thence westward to Jackson Creek and the Ibex River Valley. In the south part of the map area access is provided by the Klondike Highway to Carcross and the Annie Lake road from Robinson. East of the Yukon River a CN telecommunications is served by a road traversing rocks of the Lewes River group on Canyon Mountain.

REGIONAL GEOLOGY

The Whitehorse map area (Wheeler, 1961) includes the north limit of the Coast Mountains and the west part of the Yukon Platform (figure 1). Exposed rocks are Precambrian to Pleistocene in age (Table 1, Wheeler, 1961, page 22). The former are Yukon group gneisses and schists of metamorphosed quartz arenite, chert, limestone, and volcanic wacke. These rocks are unconformably overlain by Pennsylvanian and Permian limestone, chert, and greenstone including scoriaceous and

amygdaloidal flows, pyroclastic rocks, and sills of the Taku group which in turn are unconformably succeeded by Mesozoic eugeosynclinal strata of the Whitehorse trough, a segment of the Tagish belt (figure 1 inset).

The oldest Mesozoic rocks of the Whitehorse map area are basalts, andesites, pyroclastic rocks, and poorly sorted clastic sedimentary rocks of the Upper Triassic Lewes River group (Table 2, Wheeler, 1961, page 37). This eugeosynclinal assemblage gives way to coarse gravels and cobble conglomerate basal to the Laberge Group of Lower Jurassic age which signify rapid uplift and the start of an essentially continental non-marine succession of sedimentary rocks which constitute Middle and Upper Jurassic Laberge and Tantalus groups. Cretaceous and younger layered rocks are continental clastics and a continental volcanic suite of basalt and rhyolite. Layered rocks from Precambrian through Cretaceous age are intruded by batholiths of intermediate composition which have been mapped as Cretaceous (Wheeler, 1961) but which by field relationships may be Upper Triassic to Cretaceous in age and comagmatic with the Triassic volcanism. Post Cretaceous intrusions are relatively small, of intermediate to felsic composition, and probably related to the Continental volcanism.

Rocks older than Cretaceous are in northwest trending folds with steeply dipping axial planes. Faults of undetermined displacement trend northwest and northeast and are steep dipping.

Table I

Table of Formations Exposed in the Whitehorse
May Area (Wheeler, 1961)

Era	Period or Epoch	Formation (thickness in feet)	Lithology
Cenozoic	Pleistocene and Recent		Glacial drift, alluvium, loess, volcanic ash
			Basalt; minor pyroclastic rock
	Unconformity		
	Tertiary		
			Intrusive into lower part of Skukum group
		Skukum group (4,000+)	Andesite, basalt, rhyolite, and trachyte breccias, tuffs, and flows; 'granitic agglomerate'
Unconformity			
Mesozoic	Late Lower or early Upper Cretaceous	Coal intrusions	Pink granophyric quartz monzonite
			Intrusive contact with granodiorite
			Leucogranite, biotite granite, alaskite, kali-alaskite
			Intrusive contact
			Hornblende-biotite-oligoclase granodiorite, biotite-hornblende quartz diorite, biotite granite, hornblende diorite, gneissic porphyritic granodiorite, pegmatitic syenite
			Intrusive contact
		Hut hi group (4,000+)	Basalt, andesite, porphyritic andesite, quartz latite, and rhyolite flows, breccias, and tuffs; minor greywacke and argillite; conglomerate locally at base
			Angular unconformity (granitic intrusion?)
			Peridotite, dunite, serpentine, and pyroxenite
	Relations unknown. Ultramafic rock in contact with Laberge group		
	Upper Jurassic(?) and Lower Cretaceous	Tantalus formation (2,500)	Arkose, siltstone, conglomerate, argillite; coal
	Lower Jurassic and later	Laberge group (9,500+)	Conglomerate, greywacke, arkose, quartzite, siltstone, argillite, hornfels
Disconformity (local conformity (?), local angular unconformity (?), local granitic intrusion(?))			
	Upper Triassic	Lewes River group (10,000)	Volcanic greywacke, siltstone, argillite, limestone, limestone breccia, conglomerate; volcanic breccia, agglomerate, tuff; andesite, porphyritic andesite, and basalt
Relations unknown			
Paleozoic	Pennsylvanian (?) and Permian	Taku group	Limestone, limestone breccia, chert; greenstone and (?) pyroclastic rocks
Relations unknown			
Precambrian and later		Yukon group	Quartz-mica, quartz-chlorite, and mica schists; quartzite; feldspathic hornblende gneiss, amphibolite, epidote-amphibolite, crystalline limestone; feldspathic gneiss, <i>ill-porphyritic</i> gneiss; gneissic porphyritic granodiorite and quartz diorite

Table II

Ibex River Section of the Lewes River Group
(Wheeler, 1961)

Lagerge group	<i>Disconformity</i>	Thickness (feet)
Dark green tuff.....		10+
Division E.		
Pale grey, massive limestone containing <i>Spondylospirig lewesensis</i>		500
Division D.		
Green and dark purple volcanic greywacke, conglomerate with fragments up to a foot across mainly of volcanic, some granitic, rocks; subordinate volcanic breccia.....		1,000-1,500
Division C.		
Purple, grey, and green volcanic breccia containing blocks up to 2 feet across and a few rounded pebbles and boulders, volcanic greywacke; 60 feet of purple and grey amygdaloidal andesite and basalt flows about 700 feet above base; at base, purplish conglomerate 50 feet thick composed of purple basalt, greenstone, and limestone cobbles		1,500-1,000
	<i>Disconformity</i>	
Division B.		
Pale grey and pale pink crystalline limestone in discontinuous lenses (10 feet).....		75-100
Limestone breccia, with a few volcanic fragments 3 to 4 inches across (5 feet).....		
Conglomerate, in lenses 10 feet thick, comprising rounded cobbles 2 to 3 inches across of purple volcanic rocks (10 feet in lenses).....		
Limestone breccia, containing corals and brachiopods (5 to 10 feet).....		
Conglomerate containing greenstone, purplish basalt, and feldspar porphyry cobbles.....		
Purplish limestone breccia and purplish greywacke grading upward into purple conglomerate.....		
Grey-green, limy greywacke, interbedded with siltstone and argillite, containing <i>Halobia</i>		
Interbedded limy greywacke, in part gritty, and banded greyish green argillite, thin conglomerate beds containing pebbles of greenstone, greywacke, and limestone; some lenses of limestone about 10 feet thick.....	60	
Interbedded grey-green, locally pebbly greywacke and banded argillite (lower part contains more argillite than greywacke).....	100	
(Division B thins northward and pinches out so that Division A merges upward with Division C)		
Division A.		
Greenstone, locally containing phenocrysts of chloritized hornblende and pyroxene, volcanic breccia of green fragments in a green or purplish matrix; minor conglomerate and siltstone.....		200
Base not exposed		

Precious metals occur in quartz veins within rocks of the Precambrian Yukon Group and some plutonic rocks and, continental volcanic rocks Cretaceous and younger in age. Copper appears to be confined to skarns in limestone of the upper part of the Lewes River group of Upper Triassic age where intruded by the Whitehorse batholith of intermediate composition.

GEOLOGY OF THE WHITEHORSE COPPER BELT

General Statement

Rocks of the Lewes River group strike northwest through the belt, are in open folds, and moderately well exposed on steep hill sides (Plate 1) and in pits on copper occurrences. Much of the Whitehorse batholith is drift covered (figure 1).

The Lewes River Group

Fossils of Upper Triassic age have been identified in sedimentary rocks intercalated with volcanic rocks which Wheeler (1961) describes as the Lewes River Group. The best exposures are along the east side of the Ibex River canyon west of Fish Lake, on Canyon Mountain immediately east of the City of Whitehorse, and on Needle Mountain south of the Copper Belt (figure 1). In general, western exposures of Lewes River group include volcanic rocks limy muds containing Halobia fauna, volcanoclastic rocks, and limestone with Spondylospira lewesensis fauna whereas central and eastern exposures within the map area are typically graded beds of mud, silt, sandstones, the Spondylospira-bearing limestone



Plate #1 View of the Copper Belt looking south from Haeckel Hill towards Golden Horn Mountain.

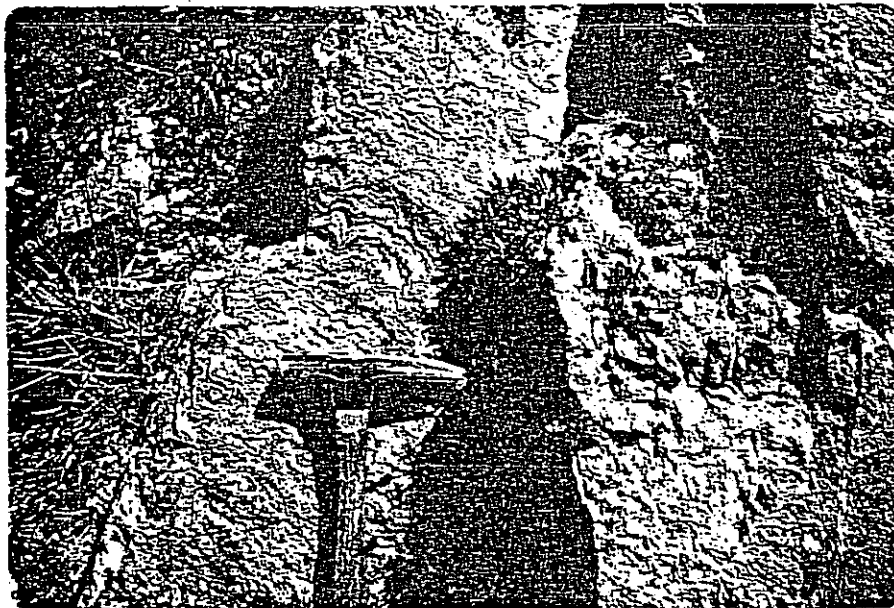


Plate #2 Algal structure in massive Halobia limestone exposed in the Ihex River Valley.

and minor volcanic rocks, indicating a decrease in volcanic influence eastward across the Belt. It appears from preliminary examination as if the copper occurrences of the Whitehorse copper Belt are associated with the Spondylospira-bearing limestone which is broadly divisible into a lower clayey argillaceous micritic unit, a middle bioclastic massive limestone, and an upper thin bedded and cherty limestone appears to thicken from west to east across the map area. Samples examined in thin section, peel section and by analyses for calcite and dolomite are listed in Table III. Most of these specimens are collected from the upper and lower parts of the limestone in an unsuccessful attempt to find conodonts for age determinations and hence are not wholly representative. The fine grain relative homogeneity, and lack of current structure indicates a low energy environment of deposition.

The Ibex River Section

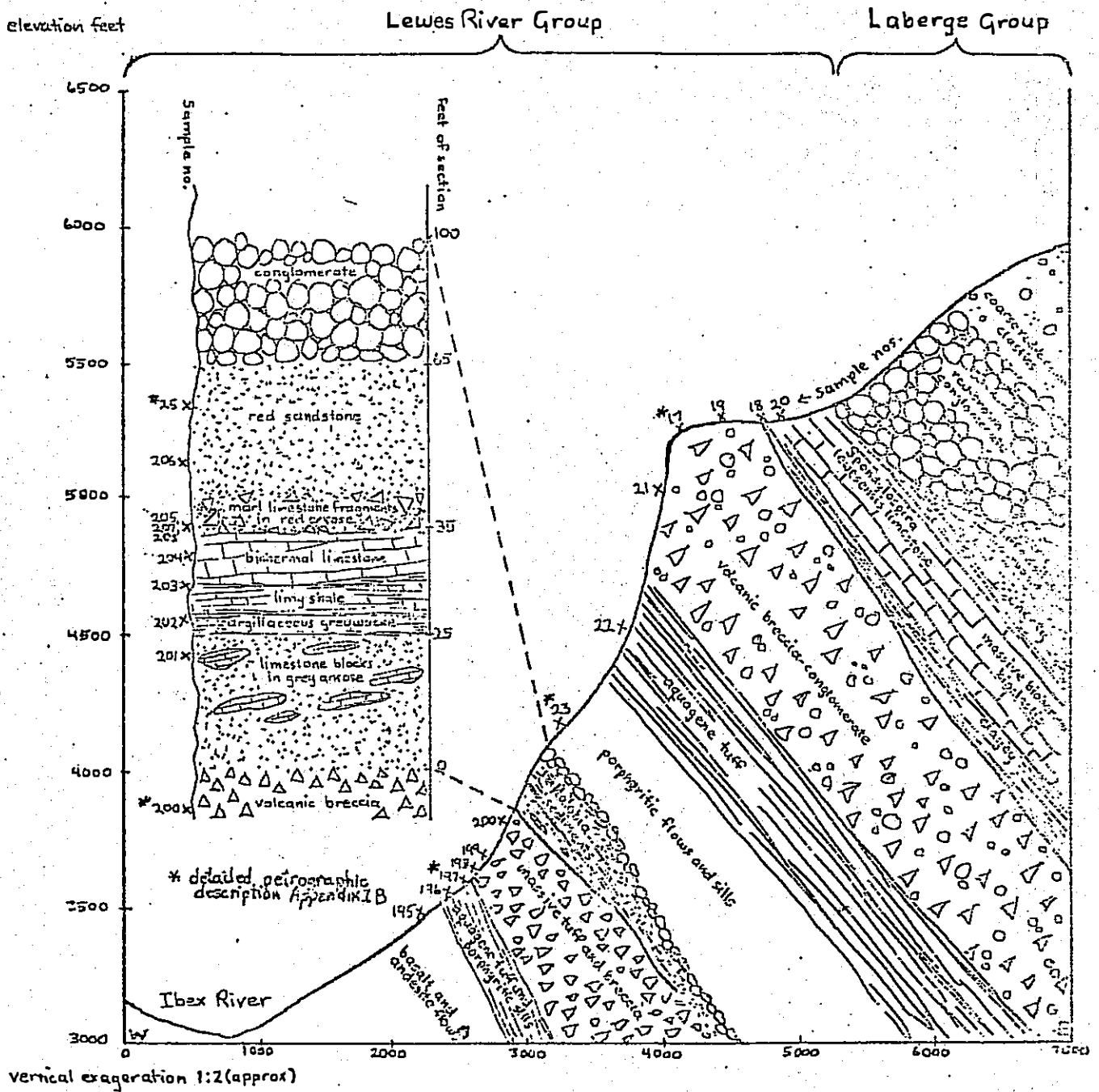
The most westerly section observed is along the east side of the Ibex River. It is described in Table 2 and Figure 2. The lower part is massive flows of basalt and andesite interbedded with fine-grained feldspathic wacke, argillite and tuff and volcanic breccia. Flows are commonly porphyritic with euhedral plagioclase, diopsidic-augite, and hornblende phenocrysts in a fine-grained matrix. Thin beds of feldspathic wacke and argillite commonly contain disseminated pyrite in a siliceous matrix. Clasts in the coarser argillite are feldspar, diopsidic-augite, hornblende, and fragments of mafic flows and tuff. The tuffs consist of

Table III

Selected Specimens of Limestone from Spondylospira-bearing horizons

Sample#	Location	Remarks	Units SiO ₂	C/D
WH 18	Ibex River	massive dolostone	3	.029
19	Ibex River	massive foss. mudstone	-	-
20	Ibex River	massive foss. packstone	10	-
20B	Ibex River	massive mudstone	7	.047
44	Needle Mt.	laminated mudstone	1	-
48	Needle Mt.	massive foss. limestone	-	-
49	Needle Mt.	massive mudstone	3	-
54	Carcross	massive mudstone	1	-
93A	Fish Lake	thin bedded oolitic dolostone	13	4.23
93B	Fish Lake	thin bedded siliceous mudstone	74	
96	Little Chief Mine	thin bedded dolomitic marble	-	.367
97	Little Chief Mine	thin bedded argillaceous	-	38.6
113	Wheeler's foss. loc. 7	massive foss. dolostone	2	1.672
117	Wheeler's foss. loc. 9	massive mudstone	-	.077
120	Wheeler's foss. loc. 18	massive mudstone	1	-
126	Canyon Mt.	thin bedded argillaceous mudstone	-	-
130	Canyon Mt.		-	-

FIG.2 CROSS-SECTION OF THE LEWES RIVER GROUP EXPOSED ON THE EAST SIDE OF THE IBEX RIVER VALLEY



matrix-supported microlite and angular fragments of an unzoned plagioclase. Upward in the section these rocks are massive layers within volcanic breccia of alternating purple and green colour. Plagioclase is generally saussaritized and the mafic minerals slightly chloritized. The volcanic breccia becomes increasingly well bedded and fragments well rounded upward in the section. There are intercalated lenses of arkose, argillite, limy greywacke, limestone and conglomerate. The limestone is lense-like and contains the Halobia fauna (Plate 2) plus carbonaceous material, pyrite and siliceous material. Limestone is overlain by pink and green coloured marl, red sandstone and conglomerate with volcanic and limestone cobbles.

The upper part of the Ibex River section is repetitive of the lower part and begins with flows and tuff overlain by volcanic breccia of purple, grey and green colour, volcanic wacke and ultimately limestone containing *Spondylospira lewesensis* and topped by chert, and tuff. The basal part of this upper limestone is a grey coloured, fine grained argillaceous dolostone with calcite crystals from 5 to 7mm in diameter and numerous subparallel calcite veinlets. The rock is homogeneous and micritic. This is succeeded by a light grey, bioclastic limestone (Plate 3) with a siliceous upper part. The rock has stylolitic bedding and is recrystallized. Contact with the overlying Laberge group is covered by drift in the Ibex-River area but a change in attitude of beds on either side of the contact suggests an unconformable

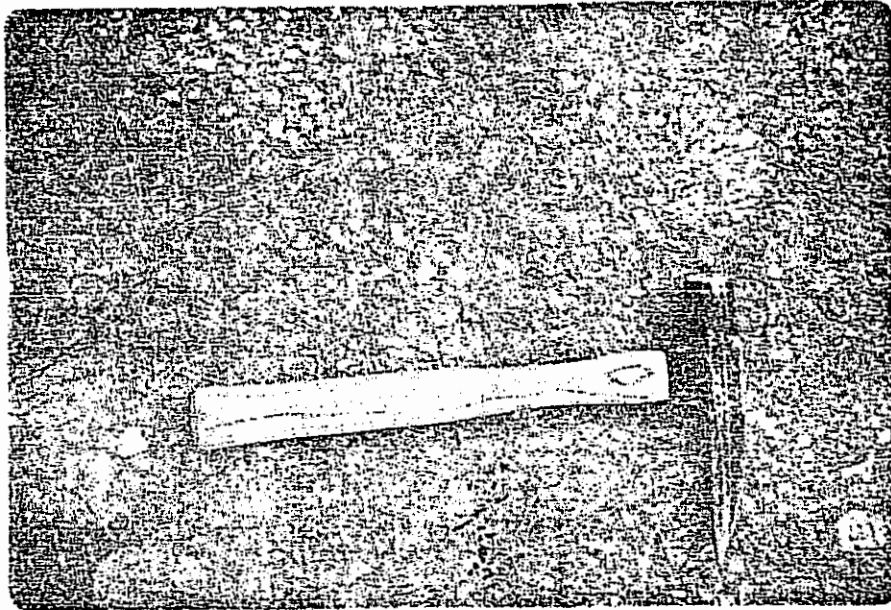


Plate #3 Massive biohermal *Spondylospira lewesensis* limestone composed of indeterminate colonial corals exposed north of Jackson Lakes.

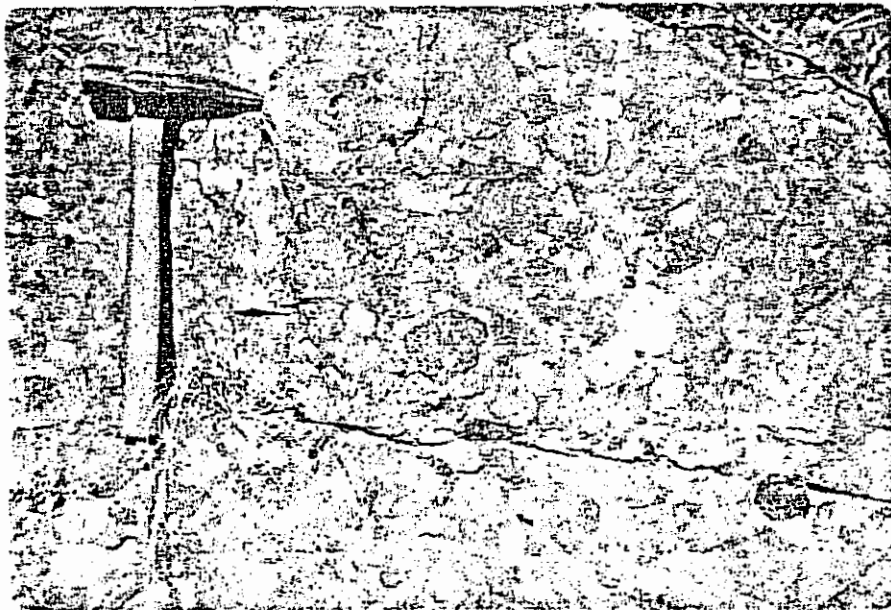


Plate #4 Laberge polymictic conglomerate observed northeast of Fish Lake.

relationship. Conglomerates of the Laberge group are polymictic, contain granitic cobbles and boulders to 4 feet in diameter (Plate 4) in a hematitic arkosic matrix.

The Fish Lake - Whitehorse Copper Belt Section

Rocks of the Lewes River group exposed in the Fish Lake area and within the Copper Belt were examined to determine which lithologies of the group contained copper sulphide minerals at the edge of the Whitehorse batholith (figure 3). From Fish Lake east through the Copper Belt rocks of the Lewes and Laberge groups are in open anticlines and synclines distributed by block faults. Individual units within the Lewes River group are difficult to follow through the sporadic outcrop of the copper belt but a tentative correlation from Fish Lake through the belt to the Little Chief mine of Whitehorse Copper Mines Ltd. is possible as illustrated in figure 4. At Fish Lake, conglomerate of the Laberge group appears to be conformable with oolitic limestone, pyritic quartzite, a limy clastic and limestone containing the *Spondylospira lewesensis* fauna and chert interbeds. This is underlain by and grades into a mottled wacke which is tuffaceous and consists of fresh and altered grains of feldspar and pyroxene in a granulate matrix of actinolite, chalcedony, calcite and hematite.

Immediately west of the Little Chief mine a thick sequence of limestone outcrops sporadically and has been described by Kindle (1964, page 5). Figure 4 illustrates this section which consists of pyritic and hematitic

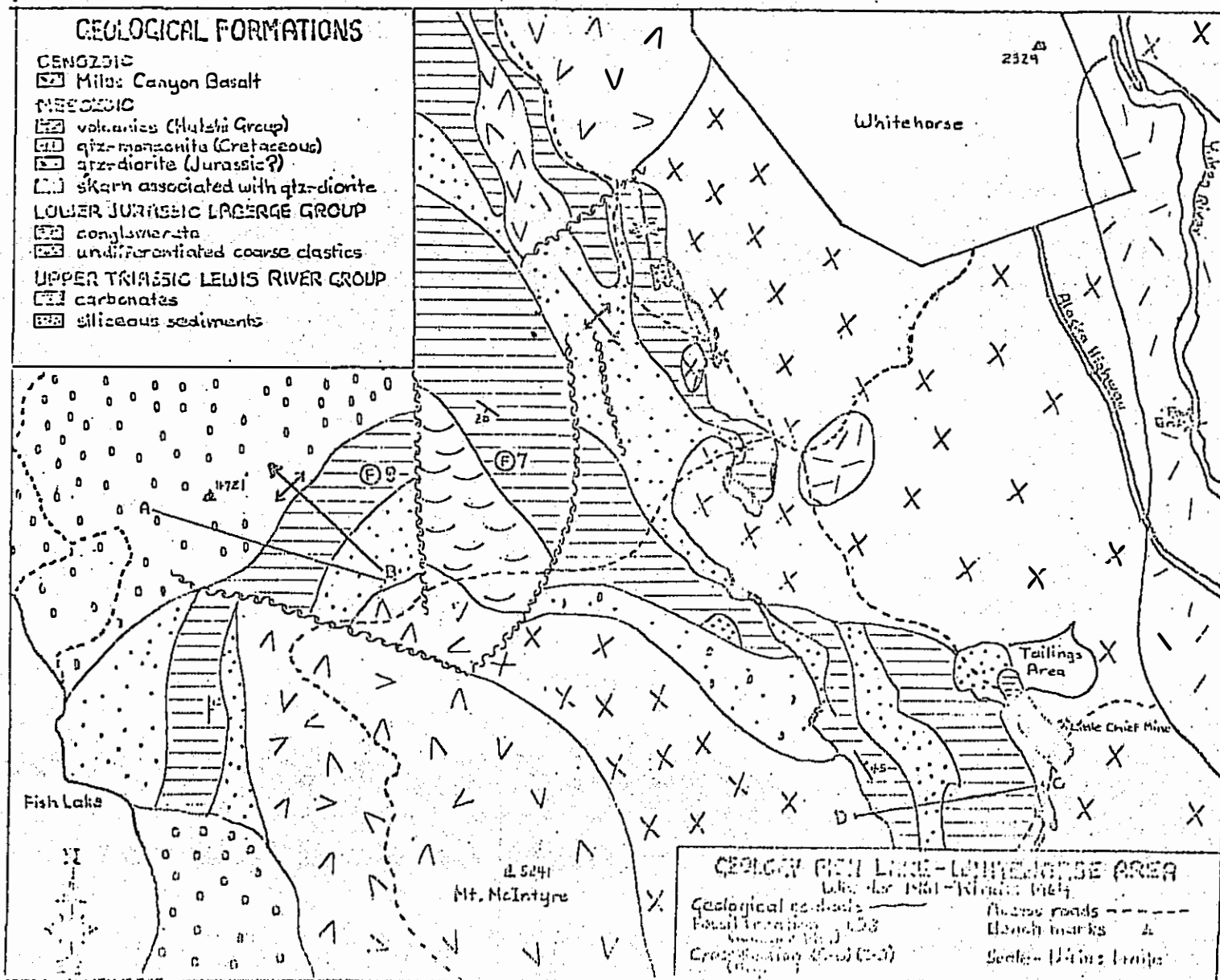
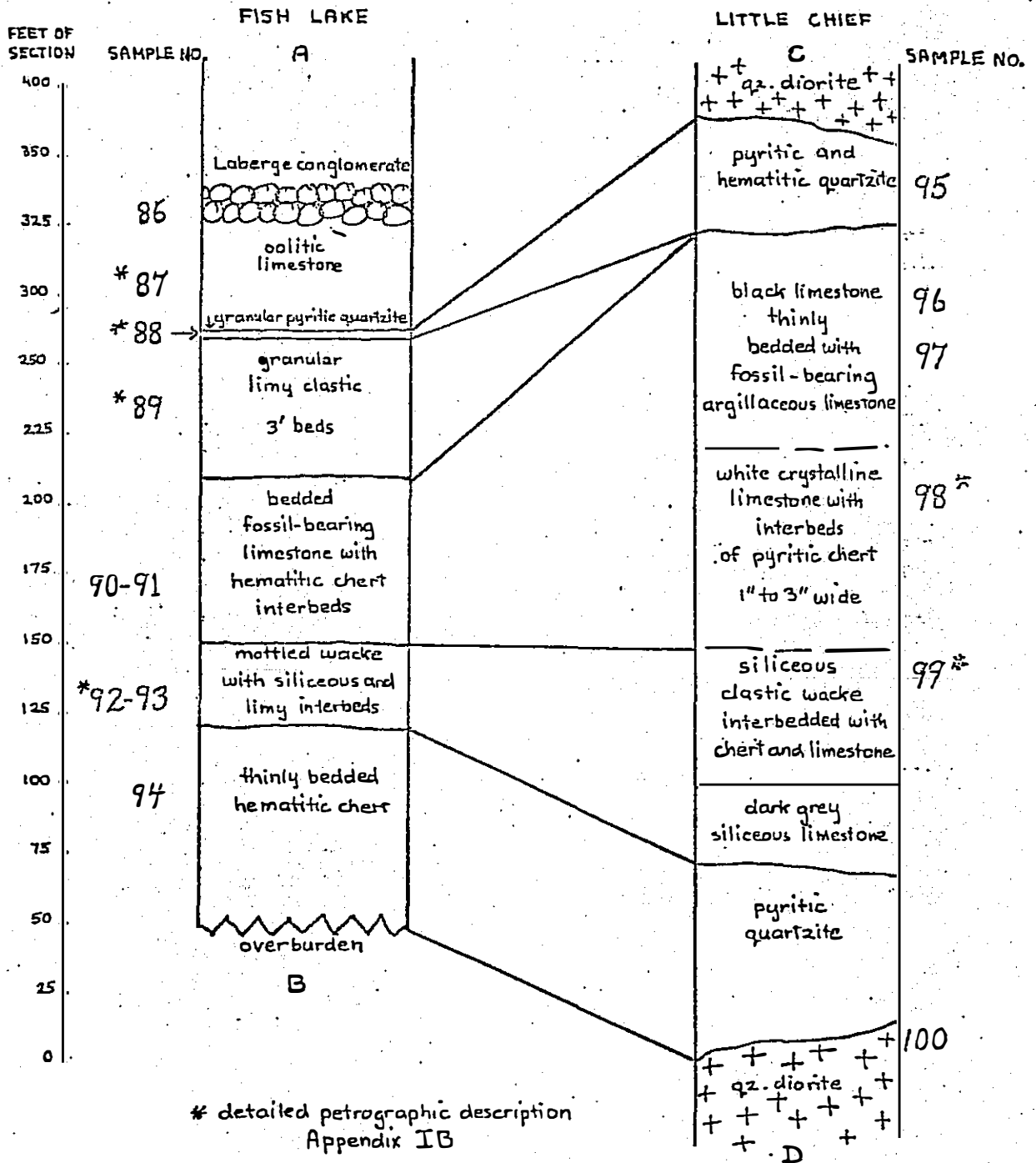


FIG. 6

FIG. 4 STRATIGRAPHIC CORRELATION OF UPPER LEWIS RIVER GROUP IN THE WHITEHORSE COPPER BELT



quartzite underlain by thin bedded black limestone with interbeds of dolomite siliceous, organic, fragmental, and argillaceous material. Stromatolitic structures are preserved in some dolomitic horizons (Plate 5). Pyrite is common in this section as are recrystallized calcite and quartz, sericite and actinolite in argillaceous seams. The clastic horizons appear to be tuffaceous with grains of plagioclase An_{30} and magnetite rather than the hematite characteristic elsewhere in the Fish Lake-Copper Belt area. Our tentative conclusion is that The Fish Lake-Copper Belt section can be correlated with the uppermost part of the Lewes River Group in the Ibex River section. These rocks probably formed in lagoonal and sabka-like evaporite environments during a period of regression leading to non-marine deposition of Lower Laberge group conglomerates.

Open pits in copper occurrences of the belt to the north and south of the Little Chief mine expose massive Skarn, crystalline limestone, clayey and argillaceous limestone, chert and quartzite as screens and inclusions within and at the contact of the Whitehorse batholith. Correlation between pits and outcrops west of the Little Chief mine is difficult but petrography and petrochemistry of some of the rocks described in appendices A and B suggest most copper occurrences are in the thinly bedded limestones and the immediately underlying more massive beds containing the *Spondylospira lewesensis* fauna described above. The thin bedded material is commonly replaced by a skarn assemblage and the more massive, more purely carbonate beds are

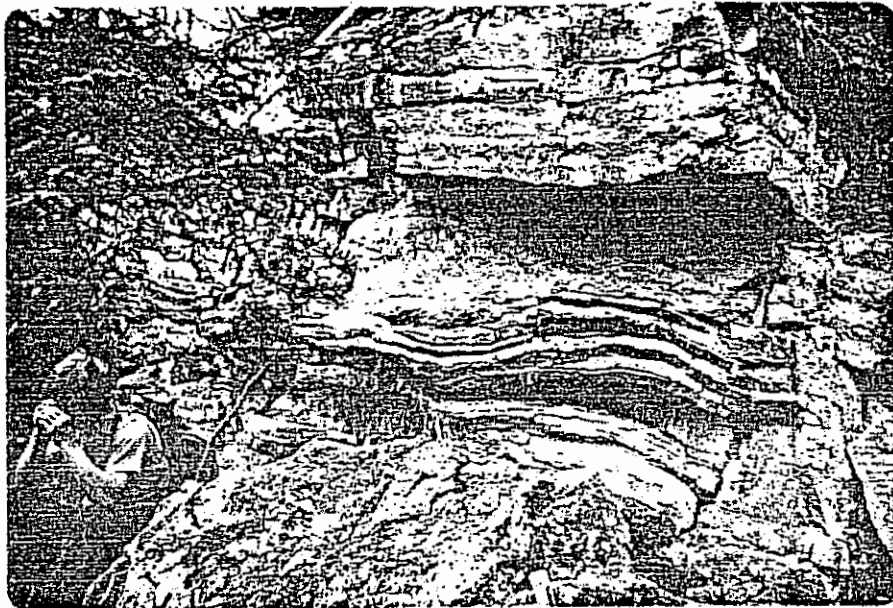


Plate #5 Preserved stromatolitic structure in dolomitic carbonates west of Little Chief Mine.



Plate #6 Massive outcropping of *Spondylospira lewesensis* limestone at White Hill near Needle Mt.

thoroughly recrystallized.

The Needle Mountain Section

Limestone with *Spondylospira lewesensis* fauna outcrops on Needle Mountain south of the Whitehorse Copper Belt and consists of 5 feet of limy grit, 2 feet of siliceous limestone with tuffaceous material, 15 feet of coarsely crystalline grey limestone, 15 feet of buff to grey coloured limestone in thin beds, and 10 feet of fossiliferous limestone. This section is overlain by a conglomerate of volcanic cobbles and cherty matrix. Plate 6 illustrates the largest outcrop of this limestone at White Hill on the east side of Needle Mountain.

The Canyon Mountain Section

On Canyon Mountain immediately east of the Yukon River and the City of Whitehorse limestone bearing *Spondylospira lewesensis* fauna is overlain and infolded with greywacke, argillite, and black slate containing ammonites which may be of Jurassic age (Wheeler, 1961, page 41). The limestone and clastic rocks appear to be conformable. The limestone is approximately 1500 feet thick at this locality, siliceous and fissile with the more massive and cleaner beds in the upper part of the section with chert and quartzite intercalations. The lower part of the section has clay and micritic intercalations. The middle section is light grey and bioclastic.

Plutonic Rocks of the Whitehorse Copper Belt

Plutonic rocks of the Whitehorse Copper Belt can in general be divided into 3 major bodies (figure 5): the Whitehorse batholith, or Copper belt intrusion is an oval shaped body of quartz diorite underlying the Yukon River Valley in an area approximately 17 by 4 miles as interpreted from airborne magnetic data; (GSC Maps 3376G, 3377 G, 11341 G) the Mount McIntyre intrusion which includes Mount Granger and Golden Horn Mountain and which is roughly 11 miles in diameter as expressed by magnetic data and, the Northwestern intrusion which underlies Haekel Hill, the Jackson Creek area, and Mount Ingram. The magnetic data suggests that only northeast of Fish Lake and at Canyon Mountain is the sedimentary cover more than 3000 feet thick over the intrusions.

The copper occurrences are associated with the upper limestone of the Lewes River Group where it overlies, is enclosed within, and intruded by the west side of the Copper Belt intrusion or Whitehorse batholith (figure 5). The copper occurrences cluster into a northern group (Group 1) near the postulated junction of the Whitehorse batholith with the Northwestern intrusion, a central group (Group 2) near the contact between the Whitehorse batholith and the Mount McIntyre intrusion, and a Group 3 in the southern part of the Whitehorse batholith. All three groups at local magnetic highs (G.S.C. Maps 3376 G, 3377 G, 11341 G.)

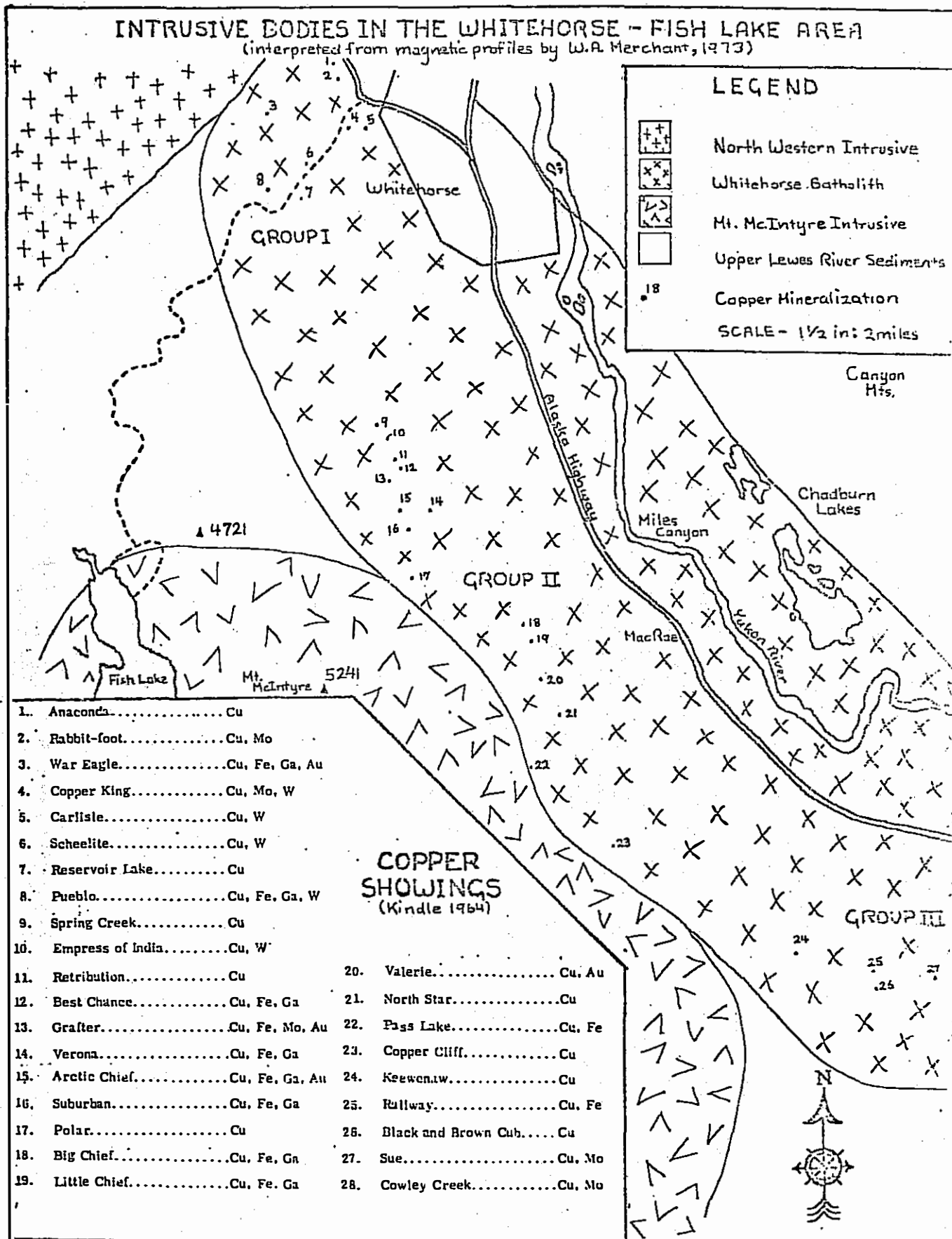


FIG. 5

Petrography

The Whitehorse batholith is essentially a quartz diorite in which hornblende predominates over biotite. The rock is massive, mesocratic and mottled with white and dark green coloured patches caused by aggregates of hornblende and plagioclase. The texture is hypidiomorphic inequigranular with anhedral grains of quartz, biotite, and sphene interstitial to interlocking subhedral grains of plagioclase and hornblende. Large plagioclases are zoned from andesine to oligocene. Small grains are unzoned and of similar composition and they coalesce into clots 1cm. in diameter. Hornblende occurs as solitary grains with green to brown pleochrism that are randomly oriented and evenly distributed throughout the rock. A few outcrops are porphyritic with coarse hornblende phenocrysts. Orthoclase may be a minor component and is frequently in myrmekitic intergrowth with quartz, it may be altered to sericite, epidote and clay minerals. Magnetite is the most abundant accessory mineral and is disseminated through the rock.

Variations are noted as in sample G-25h. which is a hornblende diorite with relict augite and only 4% interstitial quartz. Specimen G-36 had 10% quartz and 10% hornblende. Trace element content does not vary appreciably however and fresh rock generally contains about 20 ppm Cu, 15 ppm Pb, and 45 ppm Zn. Fractures are commonly coated with potash feldspar and, chloritic and sericitic alteration along fractures is characteristic. Potash feldspar replaces plagioclase in antiperthitic intergrowth (Specimen G-35) and

in this instance the rock contains anomalously high copper and zinc values.

Age of the Whitehorse batholith is problematical until some radiometric determinations are completed. The rock has been mapped as Cretaceous and of Coast Range affinity (Wheeler, 1961). It could however be as old as Upper Triassic and co-magmatic with the volcanic rocks of the Lewes River group.

The Mount McIntyre intrusion is a distinctive red brown coloured quartz monzonite which is isotropic, homogeneous, and medium grained. The essential minerals are colourless and smoky quartz, perthitic potash feldspar slightly kaolinized, and a sodic plagioclase that is normally zoned. Actinolitic-hornblende, and epidote, are less abundant and magnetite and pyrite are accessories. Rock similar to the Mount McIntyre intrusion were observed by Wheeler crosscutting foliated granodiorite and Hutshi group volcanic rocks and he inferred a mid-Cretaceous age (Wheeler, 1961, p. 99).

The Northwest intrusion exposed on the south side of Haekel Hill and in the Mount Ingram area is typically a medium to coarse grained biotite granite but some phases are biotite granodiorite. Biotite predominates over hornblende and the rock may be either porphyritic or equigranular and foliated or non-foliated. Isotropic specimens have hypidiomorphic granular textures with euhedral and subhedral grains of plagioclase and mafic minerals and anhedral grains of quartz and potash feldspar. The plagioclase is commonly

zoned and saussauritized and the potash feldspar is turbid with clay minerals. The mafic minerals are slightly chloritic. Accessory minerals include magnetite, zircon, leucocene, sphene, apatite and locally allanite. The more leucocratic varieties may contain muscovite, smoky quartz and fluorite. Porphyritic specimens have potash feldspar phenocrysts randomly oriented in a medium to coarse grained hypidiomorphic granular matrix. Where a foliation is present it is defined by alignment of mafic minerals and small lenses of quartz.

Rocks of the Northwest intrusion are comparable to rocks described by Wheeler from a large area of granite in the west part of the Whitehorse map area (Wheeler, 1961), pages 92 & 100). A potassium-argon age determination of similar rock in this area gave 223 million years (Gabrielse, 1967, p. 286). Field relationships are not definitive as to age. Contacts between the intrusion and the volcanic rocks of the Lewes River group on the north side of the Ibex River across the valley from Mount Ingram are remarkably passive suggesting perhaps a rather close relationship between the outpouring of the volcanic rocks and emplacement of the batholith.

Contact phenomena

Skarn of lime-silicate materials, with or without magnetite, and copper sulphide minerals occur sporadically at the contact of the Whitehorse batholith with limestone of the Lewes River group bearing the *Spondylospira lewesensis* fauna. Plate 7 and figure 6 illustrate skarn development in the War Eagle pit, where a relatively thin bedded

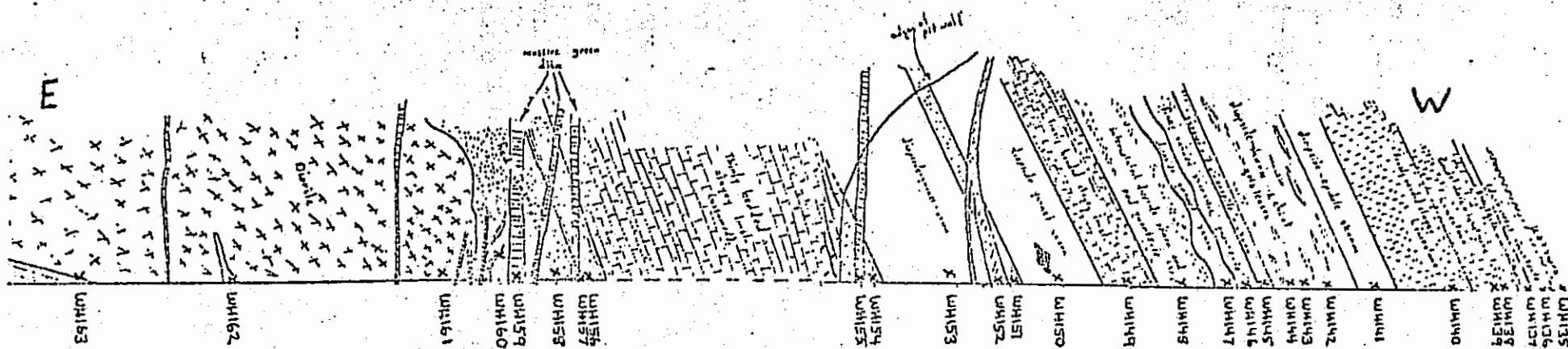
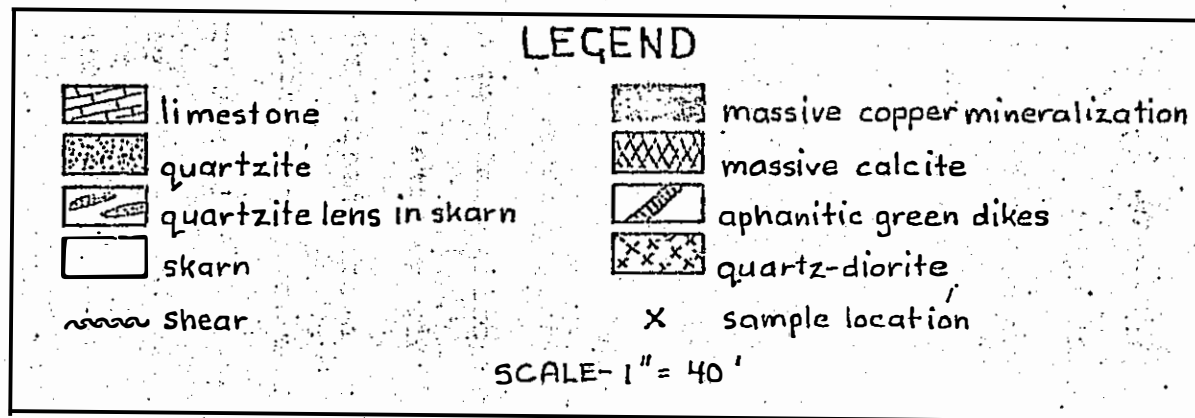


FIG.6 DETAILED MAPPING OF THE SOUTH FACE OF WAR EAGLE PIT, WHITEHORSE COPPER BELT

sequence of quartzite and marble had been hornfelsed and selectively replaced by skarn minerals adjacent to the quartz diorite of the Whitehorse batholith. Apophyses of the batholith crosscut the layered sequence and the batholith includes xenoliths and rafts of the layered rocks. Andesite dykes crosscut both the layered rocks and the batholith near the contact. Marble and dolomitic marble contain minor tremolite, diopside, wollastonite and lesser magnesite and periclase. Where the carbonate rocks have been completely replaced the assemblage may be diopside-garnet, epidote-garnet, diopside-epidote, garnet-diopside-tremolite, and garnet-diopside-wollastonite. Massive skarn is often very inhomogeneous and contains irregular patches of monomineralic garnet, epidote, and diopside. Such rock often contains pyrite, chalcopyrite, hornite, chalcocite, and magnetite intergrown with quartz and calcite. The skarn may be fractured into a stockwork pattern and fractures coated with garnet-tremolite and quartz-calcite-epidote. Fractures may also contain sulphide minerals and magnetite. Quartzite members always contain disseminated pyrite and in some instances chalcopyrite.

In general through skarnification the carbonate rocks tend to become very coarse grained and characterized by large monomineralic masses of pyroxene, garnet, serpentine, magnetite and sulphide minerals. A tentative progression of skarn development in calcic (A) and dolomitic (B) strata is as follows:

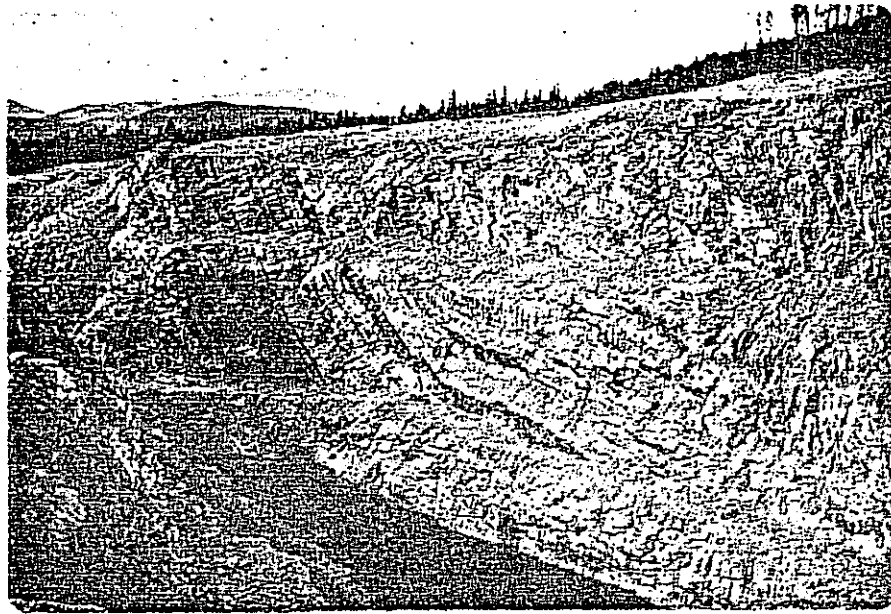


Plate #7 Interbedded anhydrous skarn and carbonaceous sediments in the War Eagle pit.



Plate #8 Hydrous skarn replacing limestone in the Little Chief pit.

	diopside ³		diopside
marble+	+	+	+
	vesuvianite		unzoned garnet

(A)

	zoned garnet		massive garnet
+ zoned garnet +	+	+	+
	copper-iron min.		mineralization

(B)

dolomite	periclase	serpentine	magnetite
	brucite		
marble	+ dolomite	+ magnetite	+ copper min.
	calcite		

Plate 8 illustrates the replacement of carbonate by massive serpentine skarn in the Little Chief Pit. Grabher (1973) describes the mineralogy and sequence of events for the Little Chief mine as follows:

"Most of the massive skarn is believed to have resulted from a major bimetasomatic (after Korzinskii and others) event, caused by the differential migration of Mg, Fe, S, Cu, Si and Al into the limestone and the migration of Ca, K and Na outward. This caused the formation of a zoned skarn in the contact zone with the following sequence:

Zoned Skarn Sequence

- 1) Marble + pyroxene
- 2) Clinopyroxene + minor garnet and magnetite
- 3) Clinopyroxene + garnet (+ garnet veins)
- 4) Clinopyroxene + zoisite + garnet (+ garnet veins)
- 5) K-spar + plagioclase + quartz + magnetite and epidote
- 6) Granodiorite to diorite (+ garnet and epidote veins)

Boundaries between zones aren't always distinct, and in particular the K-spar zone is not continuous. Thin section evidence points to the presence of an early clinopyroxene (Di?) and Orthopyroxene being replaced by later, granular clinopyroxene (Hd?) and andradite garnet, indicating Mg skarn minerals being superceded by later Fe-rich skarn.

Ore minerals, from available evidence, were introduced in two stages. Present in magnetite concentrations near original limestone boundaries as inclusions are cpy and cpy-bor or cpy-digenite grains, generally quite small (.1 - .01 mm) in size. These are believed to be early grains with chalcocite-hor or bor-cpy intergrowths since altered to cpy and digenite, in part by later mineralization involving fresh eutectic-type intergrowths of bor-chalcocite, which are larger in size and replace early magnetite grains or are molded onto them, and are most abundant in the pyroxene-rich zones 2 and 3. A later mineralizing event is chosen to explain the massive and vein-type cpy, py and pyrrhotite mineralization cross-cutting or replacing other skarn phases and associated with the contact zones between granodiorite and skarn with garnet and epidote veins. Granodiorite and diorite near the contact also contains disseminated pyrite, with cpy in clots, while at more distant locations the granodiorite holds disseminated magnetite.

Both ore events are associated with a hydrous Fe alteration assemblage which includes actinolite, biotite, chlorite and especially epidote. Veins of bor-cpy are surrounded by a halo of epidote, and bor occurs with epidote crystals cutting pyroxene skarn along fractures. A few quartz-cpy-epidote veins with alteration halos of amphibole and chlorite also occur.

The final events in the contact zone were hydrous alteration of pre-existing skarn, possibly with the addition of Mg, to serpentine, talc, chlorite and spinel; also seemingly controlled by contact of skarn and granodiorite and associated with the formation of calcite veins which cut all units in pit. Occasionally ore minerals occur in these veins, but their contribution is minor.

Secondary replacement of original Cu-sulfides has occurred to a minor extent, with secondary cpy, chalcocite and digenite occurring in serpentized areas, along with valleriite-pyrite. Valleriite surrounds bits of bor-cpy in serpentine, and where the whole rock has gone to serpentine, valleriite occurs with pyrite."

DISCUSSION

Copper occurrences of the Whitehorse copper belt and occurrences of similar character elsewhere, particularly in the Triassic of the Canadian Cordillera (Eastwood, 1965, Sangster 1969) are generally attributed to metasomatism of limestone by hydrothermal fluids emanating from an intruding magma. Metal, sulphur, and transporting fluids are believed derived from and concentrated in the magma during late stages of magmatic differentiation and crystallization. Deposition of sulphide minerals from the transporting fluids is in response to decreasing temperature and pressure and, chemical changes upon meeting the reactive limestone.

However, in the occurrences of the Whitehorse copper belt and others of this nature which we have examined, the immediately adjacent pluton may be quite variable in composition and form but the sulphide mineral deposit is invariably stratabound in relatively thin bedded, dolomitic, bioclastic and algal limestone with intercalated limy shale, and micritic mudstone. These strata are underlain and overlain by red volcanoclastic and clastic rocks isolated geographically and stratigraphically in a predominately volcanic terrain intruded by plutons which are probably comagmatic with the volcanic rocks. The carbonate rock enclosing the deposits is a common denominator to these deposits and is comparable to present day sabka or subaerial evaporite mud flats. Forming along the edges of some regressive seas (Renfro, 1974). These merge seaward into intertidal mud

flats and algal mats overlying an ooze of decaying algae in which hydrogen sulphide is generated. Interstitial brine, which can leach minor amounts of metal from the underlying volcanic and volcanoclastic rock, must rise through the reducing environment of decaying algae to reach the evaporation surface. Sulphide minerals may be deposited in stratabound configuration within that reducing environment. Initial metal concentration may therefore be dependant upon sedimentation and lithification and secondarily on reconstitution through metamorphism by an intrusion which follows closely on the heels of the volcanism.

Perhaps the orthomagmatic model of genesis has been overemphasized in explaining distribution of skarn-type copper deposits and the time has come to consider the importance of the total geology to localization and hence, to exploration for additional deposits.