GEOLOGICAL SURVEY OF CANADA

OPEN FILE 2161

Geology and ore deposits of the Timmins district, Ontario (Field Trip 6)

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edited by

J.A. Fyon
A.H. Green

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GEOLOGY AND ORE DEPOSITS OF THE TIMMINS DISTRICT, ONTARIO

[FIELD TRIP 6]

EDITED BY

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8TH IAGOD SYMPOSIUM

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Table of Contents

GEOLOGY AND ORE DEPOSITS OF THE TIMMINS DISTRICT, ONTARIO

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1.1. Introduction

The Abitibi greenstone belt (Fig. 1) continues to be an important source of mineral wealth for Canada. In Ontario, the Timmins area is known for its gold and base metal production. To the end of 1988, mines within the Timmins area (Fig. 2) produced approximately 1788 tonnes of gold (57.5×10^6 ounces), 1.75×10^6 tonnes of copper, 6.17×10^6 tonnes of zinc, and 17000 tonnes of nickel (Tables 1 and 2; Luhta et al. 1990).

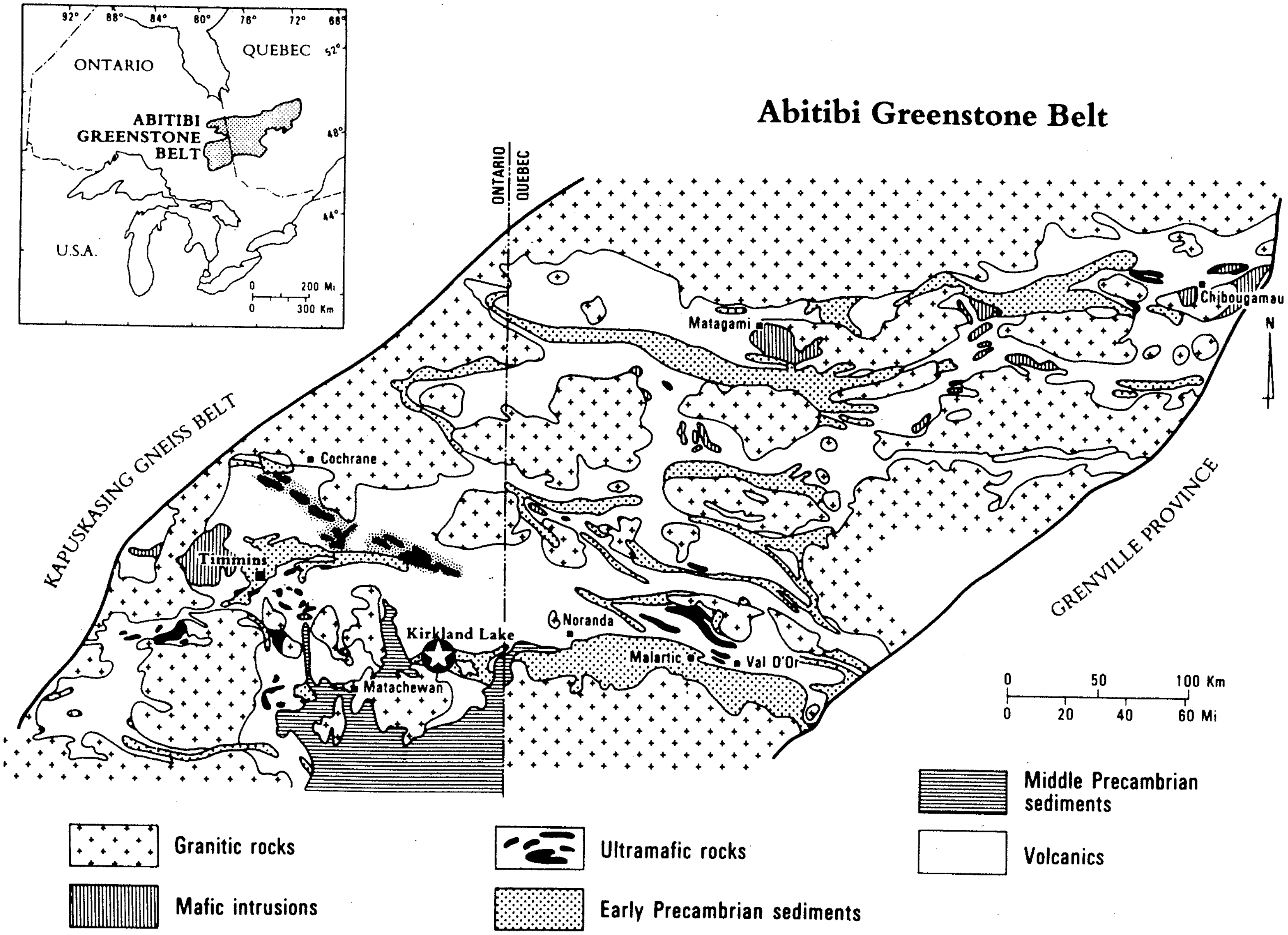
Gold production from the Timmins area (Porcupine camp) exceeds both that of the Kalgoorlie camp in Western Australia, and that of the Homestake deposits in South Dakota. Lode gold deposits are the principal source of Abitibi greenstone belt gold, which have also yielded by-product silver (Au/Ag ratios range from about 5:1 to 10:1). By-product gold and silver also accompany the massive, base-metal sulphide mineralization. Approximately 40 percent of the total Abitibi greenstone belt gold production came from the former Hollinger Mine (Giant Yellowknife Mines Limited), while the Dome Mine (Placer Dome Inc.) and McIntyre Mine (Giant Yellowknife Mines Limited) each contributed about 20 percent. Presently (1990) only a few gold mines are still in production in the historical Porcupine gold camp: Pamour #1 Mine (Giant Yellowknife Mines Limited), Bell Creek Mine - Marlhill Mine (Canamax Resources Incorporated), the Dome Mine (Placer Dome Incorporated), and the Hoyle Pond Mine (Falconbridge Gold Limited), although other properties in the area are either being re-assessed or remain on a stand-by status.

Polymetallic, base-metal mineralization in the Timmins area has been extracted from volcanic-associated, massive, base-metal sulphide deposits (e.g., Kidd Creek Mine, Canadian Jamieson, Kam-Kotia Mines, Jameland, and Genex). Of this production, approximately 90 percent has come from the giant Kidd Creek Mine (Falconbridge Limited; Table 2). Komatiite-associated, nickel sulphide mineralization occurs within komatiite-bearing metavolcanic sequences south of Timmins (e.g., Langmuir Mine and Redstone Mine- Timmins Nickel Incorporated), and to the northeast of Timmins (e.g., Alexo Mine- Noranda Limited and the Dundonald deposit- Falconbridge Limited). Past producers were the Langmuir and Alexo Mines (Table 2). The Redstone Mine (Table 2) is the only current producer (March, 1990).

1.2. Intent Of The Field Trip

The field trip to the Timmins area will focus on the following types of mineralization: 1) komatiite-associated, nickel-sulphide (Munro Township area; Alexo-Dundonald area, southern Shaw Dome area-Redstone Mine area); 2) volcanic-associated, massive, base-metal sulphide (Kamiskotia area- Canadian Jamieson Mine, Genex Mine, and Jamieson Township; Kidd Township area- Kidd Creek Mine; Munro Township area- Potter Mine); and 3) lode gold (Dome Mine, Pamour #1 Mine, Falconbridge Hoyle Mine, surface part of the Hollinger-McIntyre-Coniaurum Mine system, Bell Creek-Marlhill Mines, Hoyle Pond Mine). The following aspects of these areas will be emphasized: 1) the setting and characteristics of the deposits; 2) those empirical and quantitative data which shed light on depositional models for the ore deposits considered.

Because this field trip focuses on mineralization in the Abitibi greenstone belt, and these mineral deposits are an integral component of Abitibi greenstone belt evolution, a brief and general description of volcano-plutonic subprovinces is



(Goodwin and Ridler, 1970)

Figure 1: Generalized geology of the Abitibi greenstone belt (modified after Goodwin and Ridler 1970).

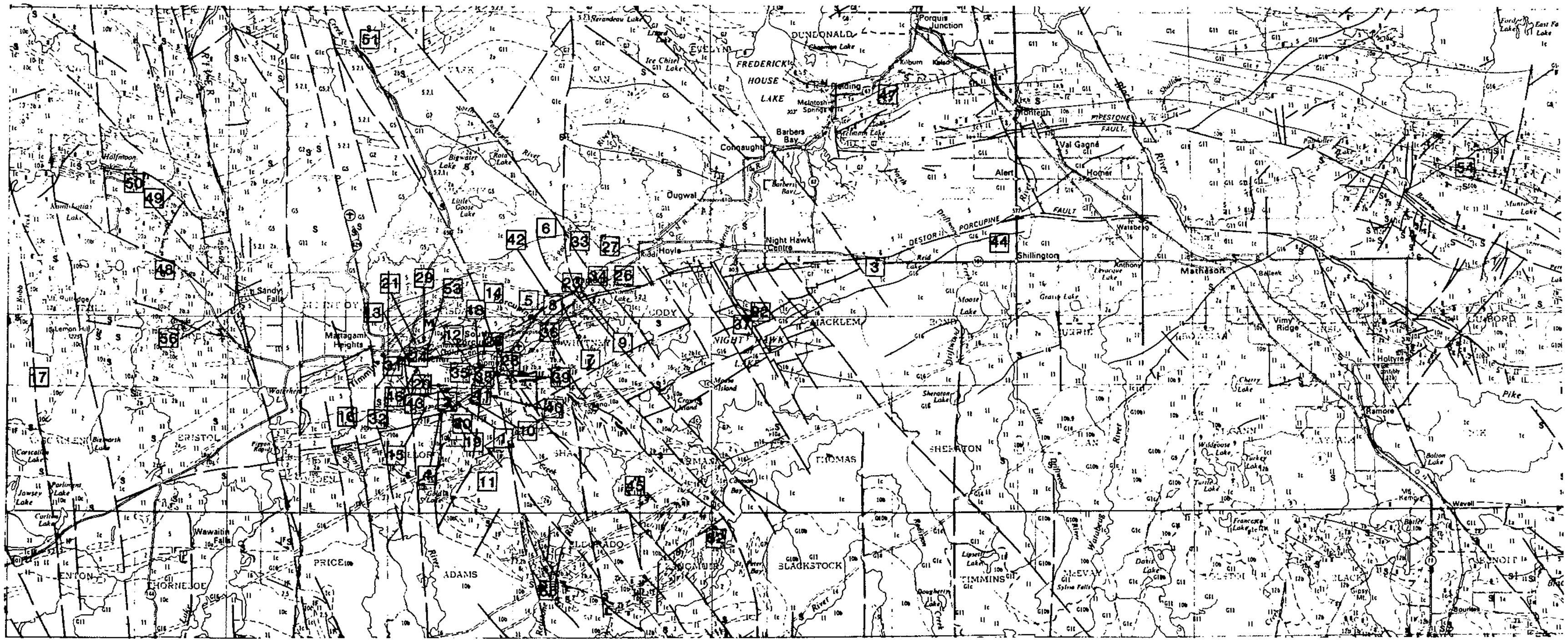


Figure 2: Distribution of past and presently producing gold and base metal mines in the Timmins - Lake Abitibi area, Abitibi greenstone belt (modified after Luhta et al., 1990). Location numbers correspond to the following mines: <u>GOLD:</u> 1. Ankerite; 2. Ankerite/March; 3. Aquarius; 4. Aunor (Pamour No. 3) 5. Banner; 6. Bell Creek; 7. Bonetal; 8 Bonwhit; 9. Broulan; 10. Cincinnati; 11. Concordia; 12. Coniaurum; 13. Crown; 14. Davidson; 15. Delnite; 16. DeSantis; 17. DeSantis; 18. Dome; 19. Faymar; 20. Fuller; 21. Gillies Lake; 22. Goldhawk; 23. Hallnor (Pamour No. 2); 24. Hollinger-Schumacher; 25. Hollinger (Pamour Timmins); 26. Hoyle; 27. Hoyle Pond; 28. Hugh-Pam; 29. McIntyre (Pamour Schumacher); 30. McLaren; 31. Moneta; 32. Naybob; 33. Owl Creek; 34. Pamour #1 (inc. #3 Pit); 35. Paymaster; 36. Porcupine Lake/Hunter; 37. Porcupine Peninsular; 38. Preston; 39. Preston NY; 40. Preston/Porcupine Pet; 41. Preston/porphyry Hill; 42. Reef; 43. Tisdale Ankerite; 44. St. Andrew Goldfields; 45. Tommy Burns/Arcadia; 46. Vipond. <u>BASE METALS:</u> 47. Alexo; 48. Canadian Jamieson; 49. Jameland; 50. Kam Kotia; 51. Kidd Creek; 52. Langmuir #2; 53. McIntyre; 54. Potter; 56. Genex.

Table 1: Gold production from the Timmins Resident Geologist's area, Abitibi greenstone belt, Ontario, Canada (Luhta et al., 1990).

MINE NAME	TOWNSHIP	YEARS OF PRODUCTION	TONS MILLED	OZ. PRODUCED	GRADE
Ankerite	Deloro	1926-1953,-78	4,993,929	957,292	0.19
Ankerite/March	Deloro	1926-1935	317,769	61,039	0.19
Aquarius	Macklem	1984,1988	100,000	10,880	0.225
Aunor (Pamour No. 3)	Deloro	1940-1984	8,482,174	2,502,214	0.30
Banner	Whitney	1927-28,-33,-35	315	670	2.13
Bell Creek	Hoyle	1987-	166,549	34,206	0.235
Bonetal	Whitney	1941-1951	352,254	51,510	0.15
Bonwhit	Whitney	1951-1954	200,555	67,940	0.34
Broulan	Whitney	1939-1954	1,146,059	243,757	0.21
Cincinnati	Deloro	1922-1924	3,200	736	0.23
Concordia	Deloro	1935	230	16	0.07
Coniaurum/Carium	Tisdale	1913-18 1928-1961	4,464,006	1,109,574	0.25
Crown	Tisdale	1913-1921	226,180	138,330	0.61
Davidson	Tisdale	1918-1920	9,341	2,438	0.26
		1988	43,850	7,301	
Delnite	Deloro	1937-1964	3,847,364	920,404	0.20
(open pit)	Deloro	1987-1988	59,067	3,602	0.77
DeSantis	Ogden	1933,1939-42 1961-1964	196,928	35,842	0.18
DeSantis	Turnbull	1926		13	
Detour Lake Mine*	Sunday Lake	1983-	4,259,000	410,209	0.10
Dome	Tisdale	1910-	45,306,914	11,563,961	0.27
Faymar	Deloro	1940-1942	119,181	21,851	0.18
Fuller	Tisdale	1940-1944	44,028	6,566	0.15
Gillies Lake	Tisdale	1929-31,35-37	54,502	15,278	0.28
Goldhawk	Cody	1947	636	53	0.08
Goldhawk (open pit)	Cody	1980	40,000	3,967	0.10
Halcrow-Swayze*	Halcrow	1935	211	40	0.19
Hallnor (Pamour No. 2)	Whitney	1928-68,-81	4,226,419	1,645,892	0.39
Hollinger--Schumacher	Tisdale	1915-1918	112,124	27,182	0.24
Hollinger (Pamour Timmins)	Tisdale	1910-1968	65,778,234	19,327,691	0.29
		1976-1988	2,615,866	182,058	0.07
Hoyle	Whitney	1941-44,46-49	725,494	71,843	0.10
Hoyle Pond	Hoyle	1985-	375,598	202,850	0.61
Hugh-Pam*	Whitney	1926,1948-65	636,751	119,604	0.19
Jerome*	Osway	1941-43,1956	335,060	56,893	0.17
Joburke*	Keith	1973-75,79-81	440,117	43,571	0.10
Kingbridge/Gomak*	Chester	1935-1936	1,387	98	0.07
McIntyre (Schumacher)	Tisdale	1912-1988	37,634,691	10,751,941	0.29
McLaren	Deloro	1933-1937	876	201	0.23
Moneta	Tisdale	1938-1943	314,829	149,250	0.47
Naybob	Ogden	1932-1964	304,100	50,731	0.17
Owl Creek	Hoyle	1981-	1,548,112	186,360	0.12
Pamour No. 1 (incl.pits 3 & 4)	Whitney	1936-	33,147,661	3,307,581	0.11
(heap leach)		1988-	401,322	4,811	
Paymaster	Tisdale	1915-1966	5,607,402	1,192,206	0.21
Porcupine Lake/Hunter	Whitney	1937-40,1944	10,821	1,369	0.13
Porcupine Peninsular	Cody	1924-27,-40,-47	99,688	27,354	0.27
Preston	Tisdale	1938-1968	6,284,405	1,539,355	0.24
Preston NY	Tisdale	1933	2,800	153	0.05
Preston/Porcupine Pet	Deloro	1914-1915		314	
Preston/Porphyry Hill	Deloro	1913-1915	46	312	6.78
Reef Mine	Whitney	1915-1965	2,144,507	498,932	0.23
Tionaga/Smith-Thorne*	Horwood	1938-1939	6,653	2,299	0.35
Tisdale Ankerite	Tisdale	1952	14,655	2,236	0.15
Tommy Burns/Arcadia	Shaw	1917	21	14	0.28-0.34
Vipond	Tisdale	1911-1941	1,565,218	414,367	0.26
TOTAL			238,769,099	57,977,157	

N.B.
ERG Resources Inc. produced 18,260 oz. Au
from treatment of 2,549,189 tons of tailings
March/88-June/89

Table 2: Base metal production from the Timmins Resident Geologist's area, Abitibi greenstone belt, Ontario, Canada (Luhta et al., 1990).

Mine	Township	Date	Ore Milled Tonnes	%Cu	%Zn	%Ni	Ag (G/Tonne)	Au (G/Tonne)
KOMATIITE-ASSOCIATED NICKEL SULPHIDE								
Alexo(1)	Dundonald	1912-19 1943-44	51,529	0.07		3.93		
Langmuir #1(2) Langmuir #2(2)	Langmuir	1973-77	220,000 320,000			1.5 (open down rake) 1.3 (open below 400 m)		
Sothman(3)	Sothman		231,000 440,000			1.3 0.9		
McWatters(2)	Langmuir		181,500 525,700			1.92 0.73		
Dundonald(3)	Dundonald		small tonnage, high grade					
Redstone(4)	Eldorado		746,120	0.09		2.29 (to a depth of 300 metres)		
Hart(2)	Eldorado		770,000			0.9 (to a depth of 300 metres		
VOLCANIC-ASSOCIATED MASSIVE BASE METAL SULPHIDE								
Canadian Jamieson(3)	Godfrey	1966-71	800,600(5)	2.39	4.05			
Jameland(10)	Jamieson	1969-72	461,805	0.99	0.88		3.50	0.05
Kam Kotia(10)	Robb	1943-44 1961-72	6,007,194	1.09	1.03		3.50	0.05
Kidd Creek Mine(6)	Kidd	1965-	81,000,000	2.06	7.18		106.00	
United Obalski(7) (Genex)	Godfrey	1965-66	254					
Potter(8)	Munro	1925-30	1,758	15.22	4.15		92.5	1.54
PORPHYRY-HOSTED CHALCOPYRITE-MOLYBDENITE								
McIntyre(9)	Tisdale	1963-81	10,162,640	0.62			0.09	0.023

(1)Noranda
(2)Timmins Nickel
(3)Falconbridge
(4)Timmins Nickel (51%) - BHP-Utah (49%)
(5)Middleton (1975), approximate tonnage
(6)Grades supplied by D. Brisbin, Geologist, Falconbridge Limited, Kidd Creek Mine
(7)Concentrate produced, P. Binney, Geologist, Falconbridge Exploration
(8)Coad, 1976.
(9)Giant Yellowknife Mines Limited
(10)Crown Held in Abeyance, pending issuance of exploratory licence of occupation (as of May 11, 1990)

provided to illustrate some Superior Province-scale lithological and mineral deposit patterns. This understanding is necessary to establish how the Abitibi greenstone belt compares, in a general way, to other greenstone belts in the Superior Province.

GENERAL GEOLOGY OF THE SUPERIOR PROVINCE

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Card and Ciesielski (1986) divided the Superior Province (Fig. 3) into four major subprovince types: volcano-plutonic, plutonic, metasedimentary, and high grade gneiss. The boundaries of these subprovinces are either major dextral, transcurrent, east-striking faults (e.g. the Quetico Fault), or zones of plutonic and metamorphic transition.

The volcano-plutonic subprovinces of the Superior Province have an east-northeasterly-trend, although individual greenstone belts within these subprovinces have variable trends and occur as ribbon or amoeboid domains. Wood and Wallace (1986), Ayres and Thurston (1985), and Thurston and Chivers (1990) summarize some descriptive

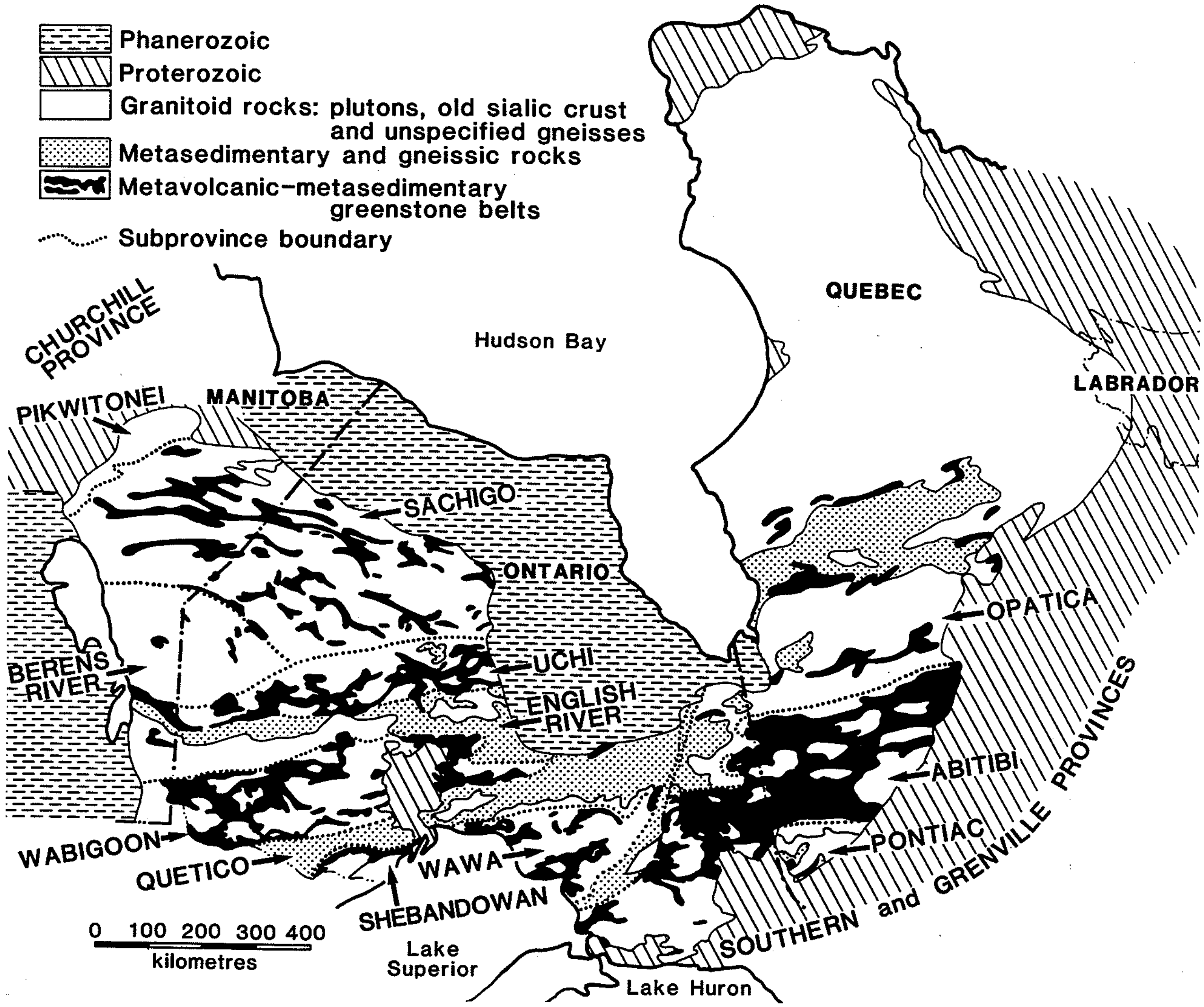

Figure 3: Subdivision of the Superior Province (after Card and Ciesielski 1986).

characteristics of greenstone belts of the Canadian Shield. The greenstone belts typically consist predominantly of ultramafic to mafic and felsic metavolcanic rocks, interlayered with clastic and chemical metasediments. In several of the belts, structural and stratigraphic sequence repetitions of volcanic rocks occur (Thurston 1986). Locally, the volcano-sedimentary sequences are unconformably overlain by shallow water to subaerial metasediments (Hyde 1980) and alkalic metavolcanic rocks (Cooke and Moorhouse 1969), which collectively, have been termed Timiskaming-like sequences.

The supracrustal rocks are intruded by tonalite-trondhjemite-granodiorite plutons, and bordered by massive, foliated, and gneissic granitoid rocks. Late Archean intrusions, emplaced into and adjacent to greenstone belts include: tonalite-granodiorite-granite (Ermanovics et al. 1979; Ayres and Cerny 1982); tonalite-diorite-monzodiorite-monzonite-granodiorite and syenite (Smith and Williams 1980; Shirey and Hanson 1984; Stern et al. 1989; Sutcliffe et al. 1990); and stocks and dikes of pyroxenite, gabbro, and lamprophyre (Smith and Sutcliffe 1988; Wyman and Kerrich 1989).

The greenstone belts have been subjected to internal folding and tilting, commonly attributed to diapiric emplacement of batholithic complexes (eg. Schwerdtner et al. 1979), so that most strata are now subvertical near batholiths. In the Abitibi greenstone belt, in areas where granitoid intrusions are not abundant, there are areas where shallow- to moderate-dipping ($<45^{o}$) sequences are preserved (e.g., Blake River Synclinorium). Strata most commonly face away from the marginal and internal granitoid bodies and form large synclinoria. Strain aureoles are normally limited to discrete zones surrounding the batholiths. The metamorphic grade of most greenstone belts ranges from subgreenschist to greenschist facies in the centre, to lower amphibolite facies at the margins, where the belts occur adjacent to gneissic terrains or are intruded by external granitoid batholiths. Amphibolite facies contact metamorphic aureoles occur around intrusions into the greenstones (Jolly 1978, 1980).

Large areas of greenstone terranes remain relatively unaffected by the strain that can be directly attributed to the emplacement of the large batholiths (Stott 1985). In these areas, stratigraphic repetitions and reversals in younging directions, thrusts, and folds have been recognized and attributed to various tectonic models, including rifting and wrench faulting (Ludden et al. 1986), thrusting (Williams 1987, McGill and Shrady 1986), and/or listric normal faulting (Hodgson 1983, Gibson et al. 1986). Stratigraphic continuity is locally disrupted by late shearing, associated with the major deformation zones. These regional deformation zones, such as the Destor-Porcupine and Larder-Cadillac "breaks" in the Abitibi greenstone belt, are prominent structural features of the greenstone belts, and can have strike continuity of several hundred kilometres.

The greenstone terranes of the northwestern Superior Province contain the oldest metavolcanic rocks dated in Ontario (3013 +/-10 Ma). Volcanic episodes were separated by long intervals of no magmatic activity. For example, three distinct felsic volcanic episodes occurred in the Red Lake belt: two major episodes, at 3000 to 2900 Ma and 2760 to 2730 Ma, and a minor episode at 2830 Ma (Corfu and Andrews 1987).

The greenstone terranes of the southeastern Superior Province contain metavolcanic rocks generally younger than 2800 Ma (Nunes and Jensen 1980; Nunes and Pyke 1980; Corfu and Grunsky 1987; Corfu and Muir 1988; Corfu et al. 1989; Marmont and Corfu 1989), although 2889+/- 9 Ma felsic metavolcanic rocks occur in the Michipicoten greenstone belt (Turek et al. 1988). In the southern part of the Abitibi greenstone belt (Abitibi subprovince), metavolcanic rocks range in age from 2747 +/- 2 Ma for the "Pacaud Group" metavolcanic rocks (Mortensen, personal communication to Corfu et al. 1989) south of Kirkland Lake and to 2700 Ma for felsic metavolcanic rocks in the Timmins ("Krist Fragmentals" or Tisdale assemblage; Corfu et al. 1989) and Kirkland Lake ("Blake River Group"; Mortensen 1987) areas. Alkalic metavolcanic rock in the Shebandowan greenstone belt (Wawa subprovince) is dated at 2689 +3/-2 Ma (Corfu and Stott 1986). In the Abitibi greenstone belt, volcanic episodes occurred at 2727 Ma, 2714 Ma, 2705 Ma and 2700 Ma (Marmont and Corfu 1989; Corfu et al. 1989; Barrie and Davis 1990). The age of greenstone belt volcanism in the Wabigoon subprovince (2755 to 2700 Ma; Davis and Edwards 1985), is generally similar to that in the Abitibi and Wawa subprovinces, except for the presence of ca. 3.0 Ga metavolcanic rock in the Lumby Lake greenstone belt (Wabigoon subprovince; Davis and Jackson 1988).

Across the Superior Province, many intrusions yield ages similar to their metavolcanic counterparts. In addition, a number of younger intrusions which cut the supracrustal assemblage have been dated. In the northwestern greenstone terranes, the post-volcanic intrusions have ages between 2720 and 2700 Ma (Corfu and Andrews 1987). In the southeastern greenstone belts, they range in age between 2690 and 2665 Ma (Corfu and Stott 1986, Corfu and Grunsky 1987, Marmont and Corfu 1989; Corfu et al. 1989). The youngest intrusion in the Timmins area is an "albitite" dike (2673 Ma; Marmont and Corfu 1989), which displays some lamprophyric geochemical characteristics (Wood et al. 1986). Late Archean rocks are cut by the Early Proterozoic Matachewan dikes, which have U-Pb zircon and baddeleyite ages of approximately 2450 Ma (Heaman 1989).

The geochronological data indicate that the latest volcanic activity occurred at different times in the greenstone belts across the Superior Province. This final volcanic activity is older in the northwestern (>2900 to 2720 Ma) than in the southeastern greenstone belts (approximately <2900 to 2700 Ma). Similarly, the emplacement of post-volcanic intrusions in the northwest (2720 to 2700 Ma) apparently terminated before that in the southeastern greenstone belts (2700 to 2673 Ma).

The development of structural zones along subprovince boundaries was diachronous across the Superior Province. In the northwestern part of the Superior Province, regionally continuous, subprovince-bounding structures were active between 2718 and 2700 Ma (Corfu and Andrews 1987; Stott et al. 1987). Similar structures along the northern boundary of the Abitibi and Wawa subprovinces were activated by 2690 Ma (Shebandowan belt, Stott et al. 1987). Ductile shear zones, interpreted to be related to the Destor-Porcupine "break" cut 2691 to 2688 Ma felsic, porphyritic intrusions and a 2673 Ma albitite dike in the Timmins area (Marmont and Corfu 1989; Corfu et al. 1989). About 100 kilometres to the east, the Destor-Porcupine "break" cuts the Garrison monzonite stock, dated at 2678 Ma (Corfu et al. 1989).

High precision U-Pb zircon geochronology combined with high quality, detailed mapping, also establish an absolute framework for the timing of mineralization. All presently known and described economic volcanic-associated, massive, base-metal sulphide (VMS) deposits occur in rocks which are younger than 2800 Ma. In the southern part of the Abitibi greenstone belt, VMS deposits occur in rock sequences which are younger than 2750 Ma. Komatiite-associated nickel sulphide mineralization is not common outside the Abitibi greenstone belt, where they also occur in rock sequences inferred to be younger than 2750 Ma (see Section 5. for additional details). Within the Superior Province, most lode gold mineralization is spatially associated with and localized by the regional, ductile shear zones, such as the Destor-Porcupine deformation zone, which were active later in the magmatic and tectonic history. In the Abitibi greenstone belt, those structures which localize gold mineralization are younger than 2690 Ma (e.g., Marmont and Corfu 1989).

REGIONAL GEOLOGY - ABITIBI GREENSTONE BELT

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The Abitibi greenstone belt (Fig. 1), the largest greenstone belt in the world, is bounded to the: 1) west by the Late Archean - Early Proterozoic, intracratonic, east-directed overthrust of the Kapuskasing Structural Zone (Percival and Card 1983, 1985); 2) south and east by the Pontiac metasedimentary-gneiss domain, the Ramsey-Algoma granitoid gneiss complex, and Early Proterozoic rift to passive margin sequence of the Huronian Supergroup (Card et al. 1972); and 3) north by the Late Archean plutonic rocks and metasedimentary gneissic rocks of the Opatica subprovince (Card and Ciesielski 1986). Several Late Archean granitoid batholiths have been emplaced into the greenstone belt (e.g., Kenogamissi, Watabeag, Round Lake, Lake Abitibi batholiths). The Abitibi greenstone belt was subdivided into an (Dimroth et al. 1984): 1) "internal" or northern domain, characterized by the presence of abundant tonalite-trondhjemite-granodiorite and anorthositic intrusions, the paucity of komatiitic flows, and greenschist or higher regional metamorphism; and 2) "external" or southern domain, characterized by the presence of fewer tonalite-trondhjemite-granodiorite intrusions, abundant komatiitic flows, and greenschist or lower regional metamorphism.

That part of the southern Abitibi greenstone belt which is preserved in Ontario, is characterized by diverse rock assemblages (Dimroth et al. 1983; Jensen and Langford 1985) and a wealth of gold (e.g., Timmins, Matachewan, Kirkland Lake, Larder Lake, Val d'Or, Malartic areas) and base metal deposits (e.g., Timmins, Noranda, Val d'Or areas). The metavolcanic, metasedimentary, and synvolcanic ultramafic to granodioritic intrusions formed between 2.75 Ga and 2.70 Ga (Corfu et al. 1989). Minor chemical sediments are predominantly oxide (chert-magnetite-hematite-iron silicate), silicate (chert-iron silicate), and sulphide (chert-pyrite-pyrrhotite-carbonaceous material) types. Thin units of interflow, sulphide-bearing, carbonaceous metasediments also occur. Widespread late felsic plutonism took place between 2.70 Ga and 2.68 Ga, during which foliated tonalite-granodiorite batholiths were emplaced before more massive granodiorite, granite, feldspar-quartz porphyry, and syenite bodies (Corfu et al. 1989; Mortensen 1987). During and subsequent to the 2.70 to 2.68 Ga magmatism, fluvial-alluvial clastic rocks (Hyde 1980) and alkalic metavolcanic rocks (Timiskaming-like; Cooke and Moorhouse 1969) were formed and are now preserved close to regional, steeply dipping, fault zones such as the Destor-Porcupine and Cadillac-Larder Lakes "breaks". Metamorphic grade within the supracrustal rocks of the Abitibi greenstone belt is generally sub-greenschist to greenschist facies and rises to amphibolite facies near intrusive bodies (Jolly 1978, 1980).

The pre-2.70 Ga metavolcanic rocks and the younger metasedimentary - metavolcanic suites form well-defined komatiitic, tholeiitic, and calc-alkalic lithostructural assemblages (e.g. Jensen and Langford 1985; Dimroth et al. 1982; Gelinas et al. 1977; MERQ-OGS 1983). These assemblages are described in the following section.

Bedding and tectonic fabrics in the southern Abitibi greenstone belt generally dip steeply to moderately (90° to 45°); however, shallow dips are present in some areas such as the core of the Blake River "group" (Jensen and Langford 1985), locally in the Timmins area (Pyke 1982, Piroshco and Kettles 1987), and east of the Kenogamissi Batholith. Folds are generally east-trending and there are south verging thrust faults, which both predate (Piroshco and Kettles 1988) and post-date (Piroshco and Kettles 1987; Thomson et al. 1948; Thomson 1948) deposition of the younger Timiskaming-like, alluvial-fluvial metasedimentary and alkalic metavolcanic rock sequence.

The Abitibi greenstone belt is cut by the steeply dipping, east-striking, Destor-Porcupine and Larder-Cadillac fault zones, which are the loci for major gold camps. These deformation zones have strike lengths which exceed 300 kilometres. The Kirkland Lake-Cadillac "break", in part, marks the boundary between the southern Abitibi greenstone belt and the Pontiac metasedimentary belt (Dimroth et al. 1983; Hodgson 1986). Steeply dipping foliations and steeply plunging lineations and minor folds characterize these zones and both dextral and sinistral displacements are reported (e.g., Hamilton 1986; Toogood and Hodgson 1985, 1986; Tourigny et al. 1989; Robert 1989). The spatial association of fault zones with the youngest supracrustal and plutonic assemblages (sediments and alkalic rocks), the development of pervasive carbonate alteration and penetrative fabrics within this assemblage, and locally, back-to-back younging directions suggests that the fault zones were active relatively late in the history of the greenstone belt.

DISTRICT GEOLOGY - CENTRAL ABITIBI GREENSTONE BELT

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In Ontario, the southern or "external" (Dimroth et al. 1982) part of the Abitibi greenstone belt is subdivided into several lithostratigraphic assemblages, using lithological, chemical, structural, and geochronological criteria (e.g., Dimroth et al. 1985). Some of the proposed assemblages correspond in part, or whole, to historic "groups" (e.g., Tisdale "group"), "series" (e.g., Vipond "series"), "formations" (e.g., "formation V" of the Tisdale "group"). In general, the contact relationships between and within those units defined as groups and formations are not well understood, but correspond to fault or shear zones. In many areas, our understanding of the nature and distribution of these units is limited because of poor bedrock exposure. Therefore, formal group and formation status is not implied, but for the sake of simplicity and familiarity, the informal historical nomenclature of metavolcanic and metasedimentary rock assemblages, used by previous workers, is retained in this text.

Recognition of litho-stratigraphic assemblages is an important component of reconstructive history of the greenstone belts. This allows interpretation of tectonic regimes in which the rock assemblages evolved. However, given the preliminary and evolving nature of this subdivision, no attempt is made to formally define the tectonic regimes represented by the assemblages.

The following are the metavolcanic and metasedimentary assemblages within areas examined during this field trip (Fig. 4):

1) Stoughton-Roquemaure assemblage;

2) Duff - Coulson - Rand assemblage;

3) Kidd-Munro assemblage;

4) Ghost Range Meta-igneous Complex;

5) Hoyle assemblage;

6) Tisdale assemblage;

7) Porcupine assemblage;

8) Timiskaming assemblage;

9) Kamiskotia assemblage;

10) Carscallen assemblage;

11) Deloro assemblage; and

12) Bowman assemblage.

4.1. Stoughton-Roquemaure Assemblage

This assemblage includes most of the "Stoughton-Roquemaure Group" of Jensen and Langford (1985). It consists predominantly of komatiitic and magnesium- and iron-rich tholeiite (Eakins 1972, Jensen 1978). South of Lake Abitibi, the assemblage is south-facing, and consists of peridotitic and basaltic komatiite, magnesium- and iron-rich tholeiite, finely layered chert, iron formation and felsic tuff horizons, all of which are interlayered with coarse-grained, gabbroic, peridotitic, and dunitic bodies. The coarse-grained mafic to ultramafic bodies are either intrusions or tabular flows (Jensen and Langford 1985).

Several sequences consist of peridotitic komatiite at the base, overlain successively by basaltic komatiite, magnesium-rich tholeiitic basalt, and iron-rich tholeiitic basalt (Jensen and Langford 1985). Within such a sequence, ultramafic and basaltic-komatiitic units generally decrease in thickness upward, whereas magnesium-rich tholeiitic basalt units increase in abundance stratigraphically upwards (Jensen and Langford 1985). These repetitive sequences vary from 300 metres to 1700 metres in thickness and show various states of completeness (Jensen and Langford 1985). The mafic and ultramafic lavas are generally either well-pillowed or massive (Eakins 1972; Jensen and Langford 1985). A thick (350 metre) iron-rich tholeiitic basalt occurs at what is interpreted to be the top of the assemblage (Jensen and Langford 1985).

Immediately north of the Abitibi batholith, the assemblage consists of north-facing, steeply dipping mafic metavolcanic rocks (Bonis sequence; Lumbers 1962, 1963). Here, the assemblage consists of porphyritic, amygdaloidal, massive, and pillowed units (Lumbers 1962) of probable tholeiitic affinity, interlayered with numerous, continuous conductive interflow metasedimentary units (Ontario Geological Survey 1989). Immediately adjacent to the Abitibi batholith, upper greenschist and lower amphibolite metavolcanic rocks bear a well developed east- to northeast-striking foliation or are gneissic (Lumbers 1962). This part of the assemblage is structurally juxtaposed against a unit of south-facing, metasedimentary rocks, located to the north (Lumbers 1962). From indirect evidence (back-to-back younging, sheared and folded lithologies, carbonatization), the interface between the Bonis sequence and the metasedimentary rocks to the north is a shear zone, which may have a thrust component (Lumbers 1962). Minor z-shaped folds along this shear zone are consistent with a dextral component of horizontal slip. This structural contact corresponds to the boundary between the "Internal" (north) and "External" (south) zones of the Abitibi greenstone belt (Dimroth et al. 1984).

Another dextral shear zone, the Cochrane-Milligan deformation zone, identified by deflected AEM conductors, occurs partly along the northern contact between the metavolcanic rocks and the migmatized metasedimentary rocks of the Opatica subprovince. It assumes a southeast-striking orientation as it cuts across the Stoughton-Roquemaure assemblage and it may merge with the Destor-Porcupine deformation zone, south of the Abitibi batholith. South of the Cochrane-Milligan deformation zone, pillow basalts generally face to the south, in contrast to the north-facing pillow basalts exposed to the north of this shear zone.

The presence of this structural discontinuity, coincident with the presence of a linear metasedimentary belt, represents a litho-structural arrangement which is typical of major discontinuities within and between subprovinces in the Superior Province.

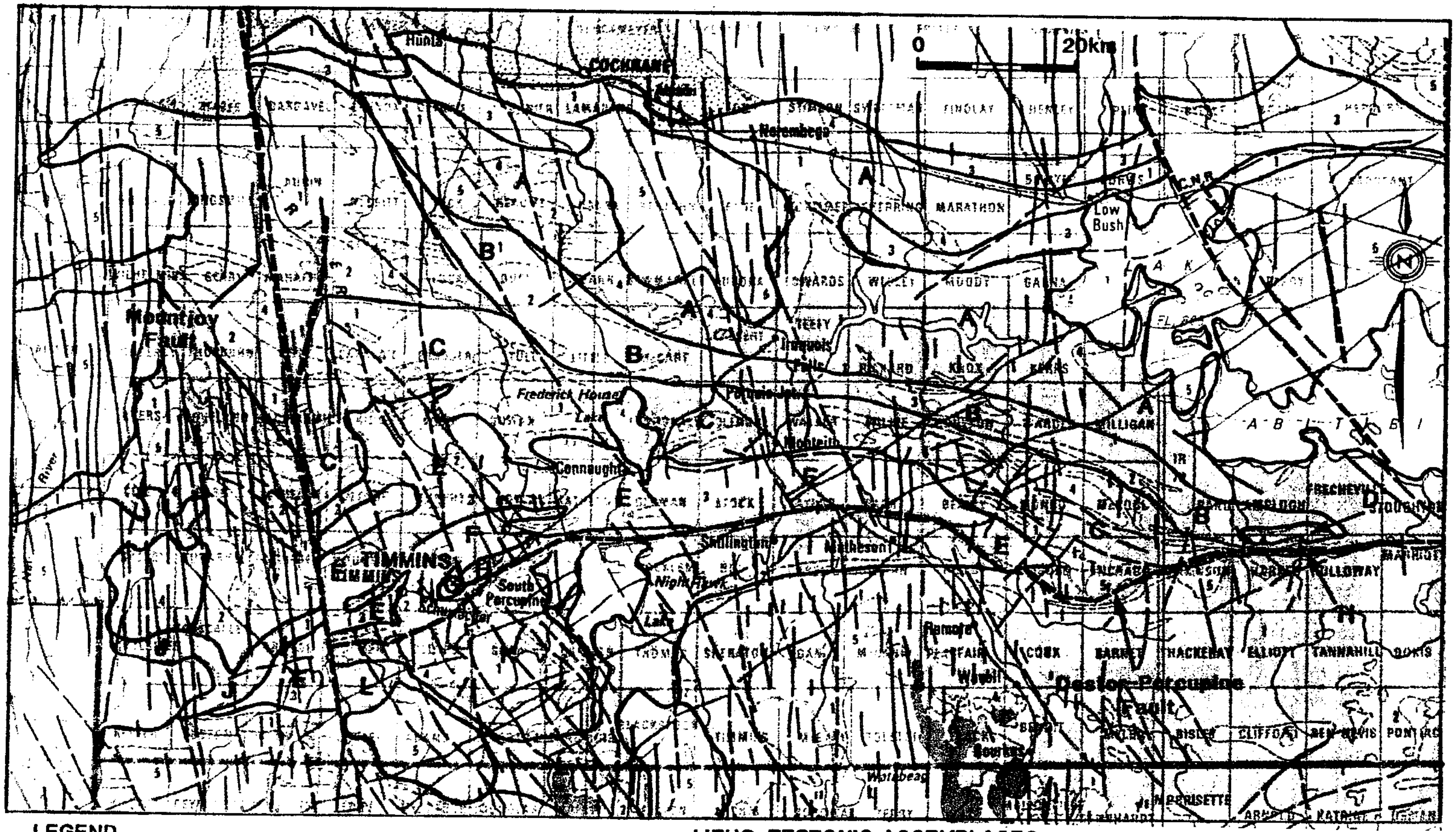
4.2. Duff - Coulson - Rand Assemblage

This is a very poorly exposed, lithologically diverse assemblage which apparently consists of metasedimentary and metavolcanic rocks. Because of poor bedrock exposure, the character and distribution of the metasedimentary and metavolcanic rocks, northwest from Rand Township, is poorly known; however, the extent of this sequence is defined by a corridor having a low magnetic signature and virtually no AEM conductors.

4.2.1. Rand Sequence

The Rand sequence occurs between the north and middle branches of the Destor-Porcupine fault zone (Jensen and Langford 1985). Although poorly exposed, this sequence is interpreted, using aeromagnetic data, to extend westerly at least as far as Warden Township (Jensen and Langford 1985). The sequence consists of steeply dipping, calc-alkalic andesite, dacite, and rhyolite tuff and tuff-breccia, interlayered with amygdaloidal, massive and pillowed calc-alkalic basalt and andesite (Jensen and Langford 1985). Neither iron formation nor metawacke occur in this area (Jensen and Langford 1985). In Rand Township, a local concentration of andesite, dacite and rhyolite breccia, intruded by numerous dikes and sills of porphyritic andesite, dacite and rhyolite, has been interpreted as an explosive vent (Jensen and Langford 1985). A strong penetrative, steeply-dipping foliation is developed (Jensen and Langford 1985). Although the sequence is generally south-facing, some small-scale folds account for local reversals.

This sequence was previously correlated with the "type" "Hunter Mine Group" in Roquemaure Township in Quebec (Dimroth et al. 1973, Jensen and Langford 1985). However, the Rand sequence contains 2715 Ma felsic metavolcanic rocks (Corfu et al. 1989), whereas the "type" "Hunter Mine Group" contains 2730 Ma metavolcanic rocks (Mortensen 1987), which precludes their stratigraphic correlation.



LEGEND

1 Ultramafic to Mafic Metavolcanics

2 Intermediate to Felsic Metavolcanics

3 Clastic Metasediments

4 Ultramafic to Mafic Intrusions

5 Granitoid Intrusions

5m Migmatites

LITHO-TECTONIC ASSEMBLAGES

A Stoughton-Roquemaure

B Duff-Coulson-Rand

C Kidd-Munro

D Ghost Range

E Hoyle

F Tisdale

G Porcupine

H Timiskaming

I Kamiskotia

J Carscallen

K Deloro

L Bowman

Figure 4: Provisional subdivision of litho-stratigraphic assemblages in part of the Abitibi greenstone belt.

4.2.2. Coulson Sequence

Well-bedded, steeply dipping, east-striking, epiclastic metasedimentary rocks crop out in southern Coulson Township (Leahy and Ginn 1961b). The facing of these metasediments is not indicated (Leahy and Ginn 1961a,b). This sequence may contain a larger component of tuffaceous material, equivalent to the calc-alkalic metavolcanic rocks exposed along strike, to the east, in Rand Township (Jensen, Geologist, Ontario Geological Survey, personal communication, 1989). Poor bedrock exposure precludes a more exhaustive discussion of this sequence.

4.2.3. Duff Sequence

To the northwest, in Beck, Duff, northeastern Tully, and Little townships, a significant volume of steeply dipping, northwesterly striking, and south-facing felsic metavolcanic rock has been intersected in diamond drill core (A.H. Green, Geologist, Falconbridge Limited, personal communication, 1990). Rock types include dacitic fragmentals, hornblende-porphyritic andesite flows, basaltic flows, and interflow chemical metasedimentary units. Little published data exist on which to base descriptions of this sequence.

4.2.4. Contact Relationships

The assemblage contacts are not exposed; however, the deflection of AEM conductor traces suggests that both contacts in the northwestern part of the assemblage are coincident with dextral shear zones. Similarly, the contact between the calc-alkalic metavolcanic rocks in Rand Township and metavolcanic rocks belonging to the Kidd-Munro assemblage to the south (discussed below) is also sheared (Satterly 1954), and therefore, stratigraphic relationships cannot be established.

4.3. Kidd-Munro Assemblage

This assemblage consists of ultramafic, pyroxenitic, and basaltic komatiite, tholeiitic picrite, magnesium-rich tholeiite, high-alumina basalt, iron-rich tholeiite, icelandite (andesite), and thin units of high-silica rhyolite (Basaltic Volcanism Study Project 1981, Chapter 1.2; see Section 7.1.2.2 for discussion of high-silica rhyolite). Variolitic, massive, and pillowed basalt units also occur (e.g., Leahy and Ginn 1961a,b; Arndt and Nesbitt 1982). Associated with these metavolcanic sequences are layered, tholeiitic (e.g., Munro Lake Complex, Centre Hill Complex, McCool Hill Complex; MacRae 1969) and ultramafic intrusions. Lithologies generally strike east to southeasterly and dip steeply. In the eastern part of the assemblage, units face both to the north and south, which is attributed, in part, to the presence of several east-striking folds and several east- to southeast-striking shear zones. Facing and dip direction of units in the western part of the belt are poorly constrained.

The most comprehensive descriptions of mafic and ultramafic flows are for those which crop out in Munro Township (Arndt and Nesbitt 1982), the location of the classic ultramafic komatiites of Pyke Hill (Pyke et al. 1973). Based on geochemical criteria, several types of basalts are recognized (Arndt and Nesbitt 1982): Type 1: LREE-depleted, flat HREE, low abundances of incompatible elements; Type 2: flat REE, enriched in incompatible elements; Type 3: Theo's flow basalts, strongly enriched in incompatible elements, slightly enriched LREE pattern, fractionated HREE; 4) Warden Township basalts, having trace element characteristics similar in some respects to those of "Type 2" basalts (enriched incompatible elements, inferred flat REE patterns). "Type 1" basalts could have been derived from a depleted mantle source (Arndt and Nesbitt 1982). All other magmas could have come from a second source which had roughly chondritic trace element ratios (Arndt and Nesbitt 1982). The extent to which these detailed petrochemical relationships, described from Munro Township, can be applied through the Kidd-Munro assemblage remains to be confirmed.

Rhyolites and high-silica 2715 Ma (Barrie 1990) rhyolites in the western part of the assemblage, near the Kidd Creek Mine, have relatively flat REE patterns ($[La/Yb]_n$ = 1-4), pronounced negative Eu anomalies (Eu/Eu^* = 0.20 to 0.61), low Zr/Y (2 to 6), high abundances of high field strength elements, and low abundances of Sc and Sr (Lesher et al. 1986). Felsic metavolcanic rocks from Beatty Township, in the eastern part of the Kidd-Munro assemblage, have an age of 2714 +/- 2 Ma (Corfu et al. 1989). This dated rhyolite is chemically similar to rhyolites in the western part of Munro Township, and provides the probable age for the komatiites in Munro Township. Rocks and associated base metal mineralization in Munro Township are discussed in more detail in Section 6.3.

4.3.1. Contact Relationships

The northern contact of this assemblage with the Duff-Coulson-Rand assemblage is not exposed, but locally appears to be coincident with a shear zone having a dextral horizontal slip component (see discussion above). The Pipestone shear zone defines the contact with the Hoyle assemblage (discussed below) to the south (e.g., Leahy and Ginn 1961a). No kinematic analysis of this shear zone has been carried out. This western contact of the assemblage is quite irregular and it is not known if this reflects a stratigraphic or structural interleaving of lithologies. It is not known if this assemblage extends to the west of the Mattagami River fault (Fig. 4).

4.4. Ghost Range Meta-igneous Complex

The Ghost Range meta-igneous complex lies just north of the Destor-Porcupine fault zone. The body has been variably interpreted as a sequence of flat-lying lava flows (Jensen and Langford 1985) or a differentiated sill (Satterly 1952, 1954; MacRae 1969). Recent mapping supports an origin as a layered lopolith (Smith and Sutcliffe 1988). The body consists of shallow-dipping (<50°) units of lherzolite (with dunite), clinopyroxenite, gabbronorite (and gabbro), and hornblende-gabbro (Satterly 1952, 1954; MacRae 1969; Smith and Sutcliffe 1988). Within the complex, a thin unit of layered felsic tuff is reported to occur between two gabbroic-textured phases (Jensen and Langford 1985), although this unit was not recognized by Smith and Sutcliffe (1988). The Ghost Range layered intrusion may be closely related genetically to other layered, tholeiitic intrusions in this area, including the Centre Hill Complex (MacRae 1969), which occurs within the Kidd-Munro assemblage (Section 4.3.).

The Ghost Range meta-igneous assemblage lies upon calc-alkalic basalts of the Rand sequence (Duff-Coulson-Rand assemblage; Section4.2.), although the contact relationship with these metavolcanic rocks is poorly constrained (Smith and Sutcliffe 1988). While shallow-dipping rocks do occur elsewhere in this eastern part of the Abitibi greenstone belt, the anomalously shallow dips of the Ghost Range meta-igneous assemblage and its inferred, disrupted contact with the underlying, more steeply dipping calc-alkalic metavolcanic rocks (Satterly 1952, 1954) of the Rand sequence (Section 4.2.1.), suggest that the present geometry of the Ghost Range intrusive body may be partly attributed to faulting.

4.5. Hoyle Assemblage

This assemblage is dominated by metasedimentary rocks interlayered with minor metavolcanic rocks. The metasedimentary rocks consist of wackes and slates, interlayered with a few conglomerate units (Hawley 1926; Harding and Berry 1938; Ferguson 1957). Carbonaceous metasediments are also present, particularly near the contact with the metavolcanic rocks to the south (e.g., Tisdale assemblage, discussed below). In the western part of this assemblage, west of the Mattagami River Fault, the metasedimentary rocks have steep, southerly dips and are south-facing (Hawley 1926; Harding and Berry 1938; Ferguson 1957). North- and south-facing wacke-slate couples, having strikes which range from east to north, occur in an isolated area in the central part of the assemblage. Conglomerate does not crop out in this area (Berry 1941). The abrupt change in facing direction over short distances (10 to 100's metres) is consistent with the presence of tight folds in this area (e.g., Berry 1941; Ferguson 1964). In the eastern part of the assemblage (Carr and Beatty townships), steeply to south-dipping, generally north-facing wacke, slate, and arkosic wacke beds occur (Prest 1951; Satterly 1951). Bedded tuffs are also reported to occur in this assemblage (Prest 1951, p. 5).

4.5.1. Contact Relationships

Along the southern boundary, the Hoyle assemblage lies in contact with the Bowman assemblage, the Tisdale assemblage, the Timiskaming assemblage, and the Eldorado assemblage.

The Kidd-Munro and Hoyle assemblages are, in part, separated by the Pipestone ductile shear zone along the northeastern extent of the Hoyle assemblage (Prest 1951). The nature of this northern contact is not well constrained to the north and northwest, where metavolcanic rocks of the Kidd-Munro assemblage appear to be interlayered with metasedimentary rocks of the Hoyle assemblage. Locally, the metasedimentary rocks of the Hoyle assemblage appear to unconformably overlie metavolcanic rocks of the Kidd-Munro assemblage; elsewhere it is probably a faulted contact (A.H. Green, Geologist, Falconbridge Limited, personal communication, 1990). The southern Hoyle assemblage is truncated by the Destor-Porcupine fault zone (e.g., Carr and Beatty townships- Prest 1951a; Thorneloe- Harding and Berry 1938).

In the central part of the area (Murphy and Hoyle townships; Dunbar 1948), east-striking couples of metavolcanic-metasedimentary rock occur; the metavolcanic units are similar to and correlated with those of the northern part of the Tisdale assemblage (Section 4.6.). These couples appear to be bounded by faults (Dunbar 1948). Thus, the contact between the Hoyle assemblage and the Tisdale assemblage, to the south, may also be tectonic.

From the inferred local unconformable relationship between the Kidd-Munro assemblage to the north (inferred to be older) and the Hoyle assemblage to the south (inferred to be younger), rocks of the Hoyle assemblage must be younger than 2714 Ma, the age of the youngest rhyolite in the Kidd-Munro assemblage (Section 4.3). Locally, along the southeastern boundary, rocks of the Hoyle assemblage is unconformably overlain by metasedimentary rocks of the Timiskaming assemblage (Section 4.8.). Therefore, deposition of the Hoyle metasedimentary rocks pre-dated the deposition of the Timiskaming-like metasedimentary rocks.

4.6. Tisdale Assemblage

This greenschist facies assemblage was previously called the Tisdale Group (Dunbar 1948; Pyke 1982), which, in the Timmins area, consists of three divisions. The basal division consists of ultramafic, pyroxenitic, and basaltic komatiites and magnesium-rich tholeiites ("formation" IV, Pyke 1982). The middle division consists of iron-rich tholeiitic basalt, interlayered with thin (<5 metres) carbonaceous metasedimentary rocks ("formation" V, Pyke 1982). Thin rhyolitic units within this division are interpreted to have formed by the coalescence of "felsic" varioles (Comba et al. 1986). This middle division, in turn, has been subdivided (Graton et al. 1933; Jones 1948; Ferguson et al. 1968) into the Northern, Central, Vipond, and Gold Centre "subgroups". More detailed descriptions of these "subgroups" are given in Section 8.2.2. The upper division of the Tisdale assemblage consists of minor accumulations of 2698+/-4 Ma (Corfu et al. 1989), calc-alkalic, felsic pyroclastic rock ("Krist" fragmentals of Ferguson et al. 1968; "formation" VI of Pyke 1982). Although interflow metasedimentary units are not abundant within the assemblage, carbonaceous metasediments are interlayered with iron-rich tholeiitic basalt (Ferguson et al. 1968). A bed of argillite is generally present between the iron-rich tholeiitic basaltic flows (Vipond "subgroup") and the felsic metavolcanic rocks at the top of the Tisdale assemblage (Ferguson et al. 1968). Intruded into this assemblage are 2691 to 2688 Ma (Corfu et al. 1989; Marmont and Corfu 1989) quartz-feldspar-porphyritic, granodioritic bodies of sodic affiliation (Ferguson et al. 1968; Burrows et al. 1986).

Although the metavolcanic units generally dip steeply and have an easterly strike, variations in strike and facing can be attributed to the presence of northwest-striking (Kayorum Syncline and South Tisdale Syncline) and northeast-striking folds (Porcupine Syncline, Central Tisdale Syncline, and North Tisdale Syncline) and several deformation zones (Hollinger Main fault, Dome fault, and Destor-Porcupine fault). Prominent deformation zones which cut rocks of the Tisdale assemblage include the east-northeast-striking Hollinger Main fault, the east-striking Dome fault, and the east-striking Destor-Porcupine deformation zone (Ferguson et al. 1968).

The Destor-Porcupine deformation zone defines the southern boundary of the assemblage. In this southern area, south-facing tholeiitic and komatiitic metavolcanic rocks are juxtaposed against a north-facing sequence of intermediate and felsic calc-alkalic metavolcanic rocks and sulphide facies iron formation of the Deloro assemblage (Pyke 1982). Other abrupt facing reversals occur elsewhere in this assemblage, across some of the deformation zones.

Ductile deformation along the Hollinger Main fault, Dome fault, and Destor-Porcupine fault affects the 2691 to 2688 Ma (Corfu et al. 1989; Marmont and Corfu 1989) quartz-feldspar-porphyritic intrusions.

4.6.1. Contact Relationships

Metavolcanic flows along the northern extent of the Tisdale assemblage are interlayered with metasediments of the Hoyle assemblage; however, it is not known if this geometry reflects a stratigraphic relationship or reflects the structural interleaving of these sequences, as inferred from data depicted by Dunbar (1948). The contact between the Tisdale assemblage and the Deloro assemblage (discussed below), to the south, is faulted and represents the surface trace of the Destor-Porcupine deformation zone. To the west, the nature of the contact between the Tisdale and Porcupine assemblages is not known. To the east, the metavolcanic rocks of the Tisdale assemblage lie in conformable contact with metasediments of the Porcupine assemblage (Pyke 1982; discussed below). The felsic metavolcanic rocks at the top of the Tisdale assemblage also appear to be conformably overlain by metasediments of the Porcupine assemblage, around the Porcupine Syncline.

4.7. Porcupine Assemblage

The Porcupine assemblage includes only those metasedimentary rocks which occur within the Porcupine Syncline. They consist of east- to northeast-striking wacke and argillite. Facing directions are poorly constrained, although easterly facings occur near the Dome Mine area (Ferguson et al. 1968) and southerly facings are recorded in the northeastern limits of the assemblage. Generally, the metasedimentary rocks lie conformably upon the 2698 +/-4 Ma (Corfu et al. 1989) felsic metavolcanic rocks at the top of the Tisdale assemblage, although, locally, they also lie in contact with basalts (Ferguson et al. 1968). Because of these relationships to the Tisdale assemblage, Pyke (1982) argued that the Porcupine assemblage was time equivalent with the entirety of the Tisdale assemblage. The eastern extent of this assemblage is truncated and unconformably overlain by the Timiskaming assemblage (discussed below).

The style of the Porcupine Syncline has been discussed by Roberts (1981) and Hodgson (1983). Roberts (1981) noted that the earliest recognizable penetrative foliation in the area is not axial planar to the Porcupine Syncline, and therefore, the syncline appears to have developed prior to the deformation event which imparted the foliations and lineations to the rocks in the Timmins area.

4.8. Timiskaming Assemblage

This northeast- to east-striking assemblage extends from the Dome Mine area, east past the Burrows-Benedict fault, where it consists of metawacke, slate, and cross-bedded metaconglomerate (Pyke 1982). East of the Timmins area to German Township, this assemblage crops out between the southern contact of the Porcupine assemblage and the Destor-Porcupine deformation zone (Burrows 1912; Laird 1931; Ferguson et al. 1968). Between the Dome Mine and Nighthawk Lake, the Timiskaming metasedimentary assemblage consists of steeply- to north-dipping, south-facing wacke, slate, and conglomerate (Burrows 1912; Ferguson et al. 1968). The unconformable relationship between this assemblage and the older ("Keewatin") metavolcanic rocks are documented at several localities in the Timmins area (see Ferguson et al. 1968 for localities), although this relationship can not be confirmed in the Nighthawk Lake area because of poor bedrock exposure (Laird 1931). No metavolcanic rock occurs within this Timiskaming metasedimentary assemblage.

A metasedimentary sequence, consisting of wacke, arkose, slate, conglomerate, and minor iron formation (Satterly 1949a), crops out further to the east in Guibord, Michaud, and Garrison townships (Satterly 1949a,b; Prest 1951b; Troop 1989), and Holloway Township (Satterly 1954). These rocks occur as relatively thin lenses, many of which are interpreted from drill hole data; thus, whether their contacts are stratigraphic or tectonic remains largely unresolved (Troop 1989). However, these metasedimentary rocks are tentatively interpreted to be of Timiskaming-like (Troop 1989). This sequence is interpreted to be bounded by the Destor-Porcupine deformation zone (Troop 1989).

4.9. Kamiskotia Meta-igneous Assemblage

The greenschist facies, Kamiskotia meta-igneous assemblage consists of a large, synvolcanic, tholeiitic intrusion (Kamiskotia gabbroic complex), which is overlain by a cogenetic, extrusive metavolcanic suite (Kamiskotia metavolcanic complex; Hart 1984). The Kamiskotia gabbro complex is subdivided into four zones on the basis of field and petrographic observations and geochemistry (Barrie 1990): 1) lower zone, consisting of partly layered, olivine-bearing cumulates along the southern and western margin; 2) middle zone, consisting of gabbro-norite and anorthositic gabbro-norite cumulates; 3) upper zone, consisting of partly layered, ferroan gabbro-norite, anorthositic gabbro-norite and hornblende gabbro cumulates; and 4) granophyric rocks of intermediate and felsic composition above and along strike with the upper zone cumulates. The upper zone - granophyre contact is irregular, and stoped blocks of partially hybridized granophyric rock within chloritized, quartz-rich upper zone gabbro occur locally (Hart 1984). Within the middle zone, a wide variety of mixed magma textures occur between gabbroic and tonalitic - granodioritic rocks. The Kamiskotia gabbroic complex is overlain by, and in part gradational with, related rhyolites, basalts and volumetrically minor evolved basalts and andesites. The Kamiskotia gabbroic complex is underlain by a sequence of mafic metavolcanic flows, called the Carscallen assemblage (discussed below). The succession of igneous units in this assemblage has a near-vertical dip and faces to the north and east (Barrie 1990).

Four 2696 to 2694 Ma hornblende-biotite tonalite to granite intrusions were emplaced into the stratigraphy (Barrie and Davis 1990). These include a tonalite which exhibits mixed magma textures with fine-grained and locally pillowed Kamiskotia gabbroic complex rocks. This tonalite is believed to have intruded the base or the margin of the Kamiskotia gabbroic complex during its crystallization, with limited magma mixing. A second tonalite which was emplaced into the sequence has a well-developed foliation fabric parallel to its margin. Marginal to the assemblage are several discrete plutons that range in composition from trondhjemite-tonalite to granodiorite-granite. Contact metamorphism to amphibolite facies accompanied the emplacement of the two external and one internal intrusions.

Mafic metavolcanic rocks of the Kamiskotia metavolcanic complex are divided into four divisions on the basis of P_2O_5, TiO_2, SiO_2 and Al_2O_3 abundance: tholeiites, iron tholeiites, icelandites and high alumina basalts (Barrie 1990). Here the term icelandite refers to a rock of intermediate composition and greater than 0.3 percent P_2O_5. Two types of icelandites are recognized, one with low TiO_2 (<2.0 percent) and the other a high TiO_2 variety.

Felsic volcanic rocks of the Kamiskotia metavolcanic complex are rhyolite and high-silica rhyolite, having relatively flat REE patterns ($[La/Yb]_n$ = 1 to 4), pronounced negative Eu anomalies (Eu/Eu^* = 0.20 to 0.61), elevated Zr and Y abundances, low Zr/Y (2 to 6), and low abundances of Sc and Sr (Lesher et al. 1986; Barrie 1990).

A possible splay off the Destor-Porcupine fault zone is present in the metavolcanic assemblage to the south (Carscallen assemblage; discussed below). North-northwest-trending mafic dikes of the Matachewan suite cut all of this stratigraphy and the Destor-Porcupine fault zone.

4.9.1. Contact Relationships

To the east, the Kamiskotia meta-igneous assemblage abuts against the Mountjoy fault zone, a north-northwest-striking, sinistral fault. The northern extent of the Kamiskotia meta-igneous assemblage is not well constrained, and its relationship to an unnamed metavolcanic assemblage to the north is not known. To the south and west, the assemblage lies in contact with the Carscallen assemblage (discussed below); however, the nature of this contact is not known (Ferguson 1957).

4.10. Carscallen Assemblage

This upper greenschist to lower amphibolite facies assemblage consists predominantly of north-facing, steeply-dipping, massive and pillowed basalt flows, showing both tholeiitic and calc-alkalic affinities, interlayered with minor amounts of high-silica rhyolite and oxide facies iron formation (Hawley 1926; Ferguson 1957; Barrie 1990). Amygdaloidal basalt flows are rare (Ferguson 1957). Extrusive komatiitic flows do not appear to be present, although an ultramafic intrusion occurs in the southern part of the assemblage. Dikes of pyroxenite and hornblendite (Ferguson 1957) and 2687 Ma lamprophyre cut the metavolcanic rocks (Barrie 1990).

Much of the assemblage is highly strained, characterized by an intense, penetrative flattening fabric and a westerly plunging (40° to 90°) elongation lineation (Barrie 1990). This shear zone is interpreted to be a splay off the Destor-Porcupine fault zone (Barrie 1990). The 2687 Ma age of a garnet-bearing ultramafic lamprophyre dike, which cuts the shear fabric, constrains the timing of shear deformation in this area (Barrie 1990).

4.10.1. Contact Relationships

The contact between the Kamiskotia meta-igneous and the Carscallen assemblages is sheared. This and the apparent suborthogonal strikes of units within the Kamiskotia and the Carscallen assemblages suggests that these two assemblages are structurally juxtaposed. To the southeast, the contact between the Carscallen and Porcupine assemblages is also not exposed. However, rocks adjacent to this contact zone are highly strained and back-to-back facing directions are recorded across the contact. Hence, the contact between the Carscallen and Porcupine assemblages is also interpreted to be a shear zone.

4.11. **Deloro Assemblage**

The extent of this assemblage is defined by the domal structure south of the Tisdale assemblage. Within the core of this domal structure are calc-alkalic andesitic and dacitic metavolcanic rocks, previously called the "Deloro Group" (Dunbar 1948; Pyke 1982). The top of this assemblage consists of units of felsic metavolcanic rock, interlayered with oxide- and sulphide-facies iron formation. Note that much of the sulphide-facies iron formation is not true iron formation as defined by Gross (1980), but is actually sulphide-bearing chert or argillaceous rock. Dunitic, peridotitic and gabbroic intrusions cut across the upper part of this assemblage.

A hornblende-bearing gabbroic rock, interpreted to be a dunitic differentiate, is 2707+/- 3 Ma (Corfu et al. 1989). This intrusion was interpreted to be genetically related to the komatiitic flows (Bowman assemblage, discussed below) which overlie the felsic metavolcanic rocks of the Deloro assemblage (Pyke 1982). In this context, the 2707 Ma age would represent the maximum age of the komatiitic flows. This genetic relationship between the dated gabbroic rock and the komatiitic flows is questioned (A.H. Green, Geologist, Falconbridge Limited, personal communication, 1990). Refinement of the stratigraphic correlations in this part of the Abitibi belt allow for the correlation of felsic metavolcanic rocks at the top of the Deloro assemblage, in Eldorado and Langmuir townships, with 2727 +/- 1.5 Ma (Corfu et al. 1989) felsic metavolcanic rocks to the southwest, in McArthur and Bartlett townships (MERQ-OGS 1983). In the context of this correlation, the felsic metavolcanic rocks at the top of the Deloro assemblage could be as old as 2727 Ma (e.g., Nunes and Pyke 1980).

4.11.1. Contact Relationships

The contact between the northern edge of the Deloro assemblage and the Porcupine and Tisdale assemblages is a ductile shear zone, which is part of the Destor-Porcupine deformation zone. The regional nature of the southern contact with the Bowman assemblage is not well constrained. Where examined in detail, this contact along the southern edge of the Shaw Dome is interpreted to be conformable and stratigraphic (Green 1978).

4.12. **Bowman Assemblage**

This assemblage corresponds largely to that defined by Goodwin (1979). The basal part of this south-facing, steeply-dipping assemblage consists of komatiitic flows which are overlain by units of tholeiitic basalt. Along the south flank of the Shaw Dome structure, a moderately (40^{o} to 70^{o}) dipping, penetrative foliation is present (Pyke 1975). These ultramafic and basaltic flows are in turn overlain by 2703 Ma (Corfu et al. 1989) felsic metavolcanic rocks, exposed in Douglas, Currie and Bowman townships.

Along the southern flank of the Shaw Dome, komatiitic flows at the base of the Bowman assemblage appear to be interlayered with calc-alkalic felsic rocks and iron formation which occur at the top of the Deloro assemblage. While this interlayered geometry may represent the structural interleaving of these rock units, sulphide-rich metasediments appear to have been assimilated by the komatiitic metavolcanic flows during their effusion (Green 1978). This suggests that sulphide-facies iron formation was in place, along the paleo-sea floor, at the time when komatiitic flows erupted onto the sea floor. It is assumed, therefore, that the contact between the Bowman and Deloro assemblages, at least in this area, is stratigraphic. To the east and west, the Bowman assemblage lies in fault contact with the Timiskaming and Porcupine assemblages (see discussion above).

MINERAL DEPOSITS

A. Fyon[1] and A.H. Green[2]

The deposit-scale characteristics of deposits of several types, that are represented in the Timmins area, are described in the following sections. These descriptions provide the visitor with an overview of the geological characteristics of the geological settings and related deposit types. These descriptions form the basis for depositional models. Accompanying each descriptive component, a tour guide is included. For some mines, the guides are very brief, and of a philosophical nature, because active mining prohibits the definition of a firm tour far in advance.

5.1. Time and Space Relationships

In this section, the mineral deposits are considered within the framework of the proposed regional geological setting (Section 4.) and the available geochronological constraints. Relevant gold and base metal production data for mines in the Timmins area are summarized in Tables 1 and 2.

5.1.1. Volcanic-associated, Massive, Base Metal Sulphide Mineralization

In the southwestern part of the Abitibi greenstone belt, polymetallic, massive, base-metal sulphide mineralization occurs in the Kidd-Munro and Kamiskotia assemblages. At the western end of the Kidd-Munro assemblage, the giant (Table 2), stratiform, polymetallic Kidd Creek deposit occurs associated with a sequence of massive to autobrecciated flows and pyroclastic felsic metavolcanic rock and effusive and intrusive mafic and ultramafic igneous rocks (see Section 7.2.). In the eastern part of the Kidd-Munro assemblage, copper-zinc mineralization at the Potter Mine is hosted by hyaloclastite units, within a sequence of tholeiitic olivine basalts and komatiites (Coad 1976; see Section 6.3.3.). Felsic metavolcanic rocks within the Kidd-Munro assemblage have ages of 2714 +/-2 (Beaty Township, immediately west of Munro Township; Corfu et al. 1989) and approximately 2717 Ma (Kidd Creek rhyolite; Barrie and Davis 1990). These dates provide a constraint on the probable age of the Kidd Creek and Potter Mine polymetallic, massive sulphide mineralization in this assemblage.

Polymetallic, massive sulphide mineralization also occurs within the Kamiskotia meta-igneous assemblage, associated with felsic and mafic metavolcanic rock within the Kamiskotia metavolcanic complex (see Section 7.1.). Zircon ages for the Kamiskotia gabbroic complex and the Kamiskotia rhyolite are 2707+/-2 Ma and 2705+/-2 Ma, respectively (Barrie and Davis 1990). Hence, the polymetallic massive sulphide deposits in the Kamiskotia area appear to have formed approximately 10 Ma after those in the Kidd-Munro assemblage.

Polymetallic, massive, base-metal sulphide mineralization occurs elsewhere in the southern Abitibi greenstone belt in older (e.g., Normetal deposit in 2730 +/-1.5 Ma felsic volcanic rocks; Mortensen 1987) and younger (e.g., Noranda deposits in 2700 Ma felsic metavolcanic rock; Mortensen 1987) metavolcanic assemblages.

5.1.2. Komatiite-associated, Nickel-sulphide Mineralization

Komatiite-associated, nickel-sulphide mineralization occurs in the Kidd-Munro and Bowman assemblages (see Sections 6.2 and 6.3). Along the south flank of the Shaw Dome several concentrations of nickel-sulphide mineralization occur in association with komatiitic flows of the Bowman assemblage (Section 4.12.), which overlies dacitic to andesitic metavolcanic rocks of the Deloro assemblage (Section 4.11.). This nickel sulphide mineralization lies along the same stratigraphic horizon as the thickest accumulation of sulphidic metasedimentary rocks.

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The age of associated felsic metavolcanic rock is not directly known. A hornblende-bearing gabbroic rock, interpreted to be a dunitic differentiate which was genetically related to the komatiitic flows of the Bowman assemblage (Section 4.12.), has an age of 2707+/- 3 Ma (Corfu et al. 1989). This intrusion cuts the felsic metavolcanic rocks of the Deloro assemblage (Pyke 1982). In this interpretative context, the 2707 Ma mafic intrusion age would represent the maximum age of the komatiitic flows at the base of the Bowman assemblage, which host the nickel sulphide mineralization. However, this genetic relationship between the dated gabbroic rock and the komatiitic flows is questioned (A.H. Green, Geologist, Falconbridge Limited, personal communication, 1990), and refinement of the stratigraphic correlations in this part of the Abitibi belt are consistent with an alternative age estimate.

Felsic metavolcanic rocks at the top of the Deloro assemblage, in Eldorado and Langmuir townships, are correlated with 2727 +/- 1.5 Ma (Corfu et al. 1989) felsic metavolcanic rocks which crop out in McArthur and Bartlett townships, 20 km to the southwest (Pyke 1982; MERQ-OGS 1983). In the context of this stratigraphic correlation, the felsic metavolcanic rocks at the top of the Deloro assemblage, which underlie the nickel sulphide mineralization, could be as old as 2727 Ma (e.g., Nunes and Pyke 1980). Felsic metavolcanic rocks in Douglas Township, which are interpreted to lie at the top of the Bowman assemblage, have an age of 2703+/-1.5 Ma (Corfu et al. 1989). Thus, based on geological correlation, the age of the nickel sulphide mineralization along the south edge of the Shaw Dome is bracketed between 2727 Ma and 2703 Ma. Considering the stratigraphic position of the mineralization at the base of the Bowman assemblage, the age of this mineralization may be closer to 2727 Ma.

Komatiite-associated, nickel-sulphide mineralization also occurs northeast of the Timmins area, in the Dundonald Township area (e.g., Alexo and Dundonald deposits; see Section 6.2.). Although no rocks in this immediate area have been dated, these komatiites are interpreted to occur within the Kidd-Munro assemblage. Felsic metavolcanic rocks, interlayered with komatiites in this assemblage, have an age of about 2717 to 2714 Ma (Corfu et al. 1989; Barrie and Davis 1990).

Given the interpreted age of komatiites in the Kidd-Munro assemblage (2714 to 2717 Ma; Corfu et al. 1989; Barrie and Davis 1990), and the inferred 2727 Ma age of rhyolites which are correlated with footwall rhyolites beneath the Shaw Dome nickel sulphide deposits, the Dundonald Township nickel sulphide deposits could be as much as 10 Ma younger than those along the south flank of the Shaw Dome. However, the age of the Dundonald nickel deposits (2714 to 2717 Ma) falls within the bracketed age range of the Shaw Dome nickel deposits (2727 to 2703 Ma). Hence, it is not possible to state unequivocally whether or not komatiite-associated, nickel sulphide deposits formed during more than one period in this part of the Abitibi greenstone belt. To resolve this question, geochronological samples of rhyolite from the southern Shaw Dome area must be collected.

5.1.3. Gold Mineralization

Approximately 1780 tonnes of gold have been extracted from auriferous, quartz vein arrays in the Porcupine camp (Table 1). While the volcanic-associated, massive base-metal sulphide and komatiite-associated nickel-sulphide mineralization can be temporally related to specific metavolcanic sequences, lode gold quartz vein systems in the Timmins area are spatially related to, but post-date late intrusive rocks,such as the Pearl Lake porphyry intrusion, and late deformation zones, such as the Destor-Porcupine, Hollinger Main, and Dome shear zones. The gold mineralization formed late in the Archean geological history of the Timmins area. Auriferous quartz veins cut the 2691 to 2688 Ma quartz-feldspar-porphyritic intrusions and a 2673+6/-2 Ma albitite dike (Corfu et al. 1989; Marmont and Corfu 1989).

Auriferous quartz vein arrays cut many different rock types, belonging to different assemblages. Mineralization at the Dome, Hollinger-McIntyre-Coniaurum, Pamour #1, Hoyle Pond, Owl Creek, Marhill and Bell Creek Mines cuts iron- and magnesium-rich tholeiitic basalt and komatiitic rocks of the Tisdale assemblage (see Sections 8.). Metasedimentary wackes of the Porcupine and Timiskaming assemblages are host to gold mineralization at the Pamour #1 and Dome Mines. The porphyry intrusions, within the Tisdale assemblage, are host to gold-quartz veins in the Hollinger-McIntyre-Coniaurum system (Section 8.2).

KOMATIITE-ASSOCIATED NI-CU-PGE MINERALIZATION

A. Green[1] and D. MacEachern[2]

The most important association of nickel mineralization in the Timmins area is the komatiite-hosted one, and the area represents one of the best examples of this type outside of the type example at Kambalda in the Yilgarn block of Western Australia.

The purpose of this chapter is to provide basic information on nickel deposits of this association in the Timmins area, and on the komatiites and other rocks with which they are closely spatially associated. It is the intention to provide information of a nature that will be helpful in the development and refinement of ore deposit models for these deposits. Some specific descriptions of field trip stops are given but, as with other sections of the guide, it is not possible to guarantee access to mines at the time of writing this guide.

6.1. Geological Setting

The komatiite suite of rocks, from basalt, pyroxenitic basalt, peridotite and dunite (Arndt and Nisbet 1982) are well represented in the southern half of the Abitibi Belt, as shown on figure 1. These rocks are most readily identified by the distinctive spinifex texture, which is relatively common in the upper parts of the flows of basaltic to pyroxenitic to peridotitic composition. In areas of poor outcrop, the full extent of komatiites is difficult to determine, hence the map is only an indication of their minimum extent.

Sufficient evidence from precise U-Pb dating shows that the komatiites are not all of the same age (see Sections 4.3, 4.6., 4.11.). However, there are insufficient data to confirm the probably different ages of the komatiites hosting nickel deposits in the Alexo-Dundonald and Shaw-Bartlett Dome areas.

6.2 Nickel Deposits of the Timmins Area

Known deposits in the Abitibi belt are clustered around the Timmins, Ontario and Malartic, Quebec areas (Fig. 1). The only known dunite-hosted deposit of the Mt. Keith association is the Dumont in Quebec (Duke 1986). All other known deposits are associated with peridotitic komatiites, variously interpreted as flows and sills. These are most commonly known as the Kambalda type of deposits. Of the nine nickel deposits in the Timmins area (Table 2) eight are hosted by komatiites. The ninth, the Montcalm deposit, is hosted by a tholeiitic intrusion. It has been described in detail by Barrie and Naldrett (1989). The deposits are listed, with estimates of their sizes and grades, in Table 2.

6.3. Pyke Hill, Munro Township

The komatiites exposed on Pyke Hill in the centre of Munro Township, Ontario (Fig. NI1, NI2), have become accepted as a type example of ultramafic flows. Many of these flows are layered with spinifex-textured upper parts and olivine cumulate lower parts (Pyke et al. 1973). There is a regular variation in the size and orientation of skeletal olivine grains in the spinifex-textured lava, from fine, randomly-oriented tablets at the tops of the flows, to larger, parallel plates lower down. The presence of spinifex texture has become recognized as a diagnostic feature of komatiite flows (Nesbitt 1971; Donaldson 1982; Arndt and Nisbet 1982), and the distribution and variation in size of olivine grains in spinifex textures are commonly used to delineate flow units and to determine facing directions in sequences of flows (Pyke et al. 1973; Barnes et al. 1974; Pyke 1982).

The Pyke Hill outcrop is unique and has already suffered damage from visitors. Please do not use hammers or dislodge samples here. This outcrop lies 300 metres east of the abandoned Potter Mine, at the edge of the tailings pond. The outcrop is comprised of unusually well exposed and little altered

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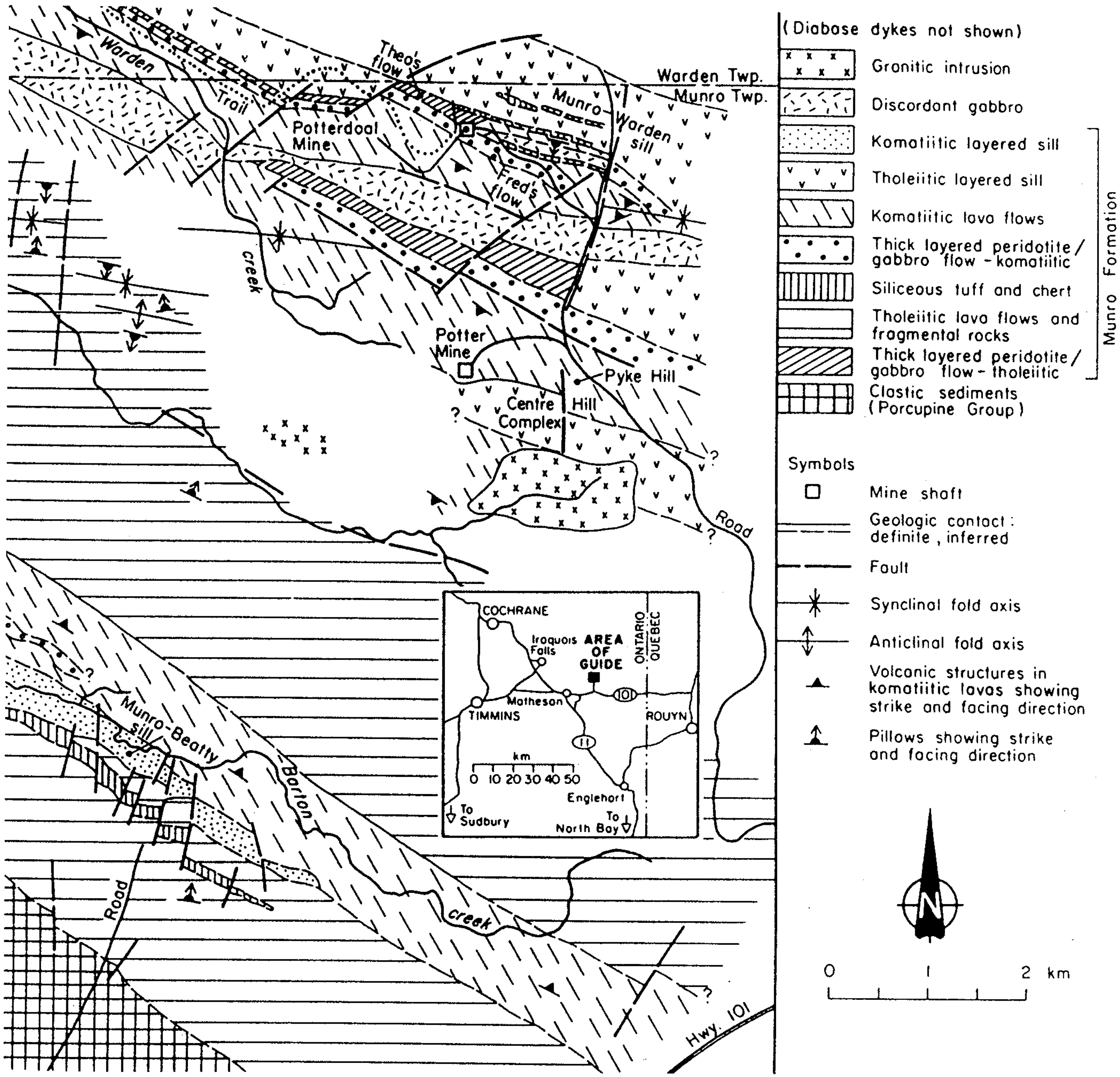
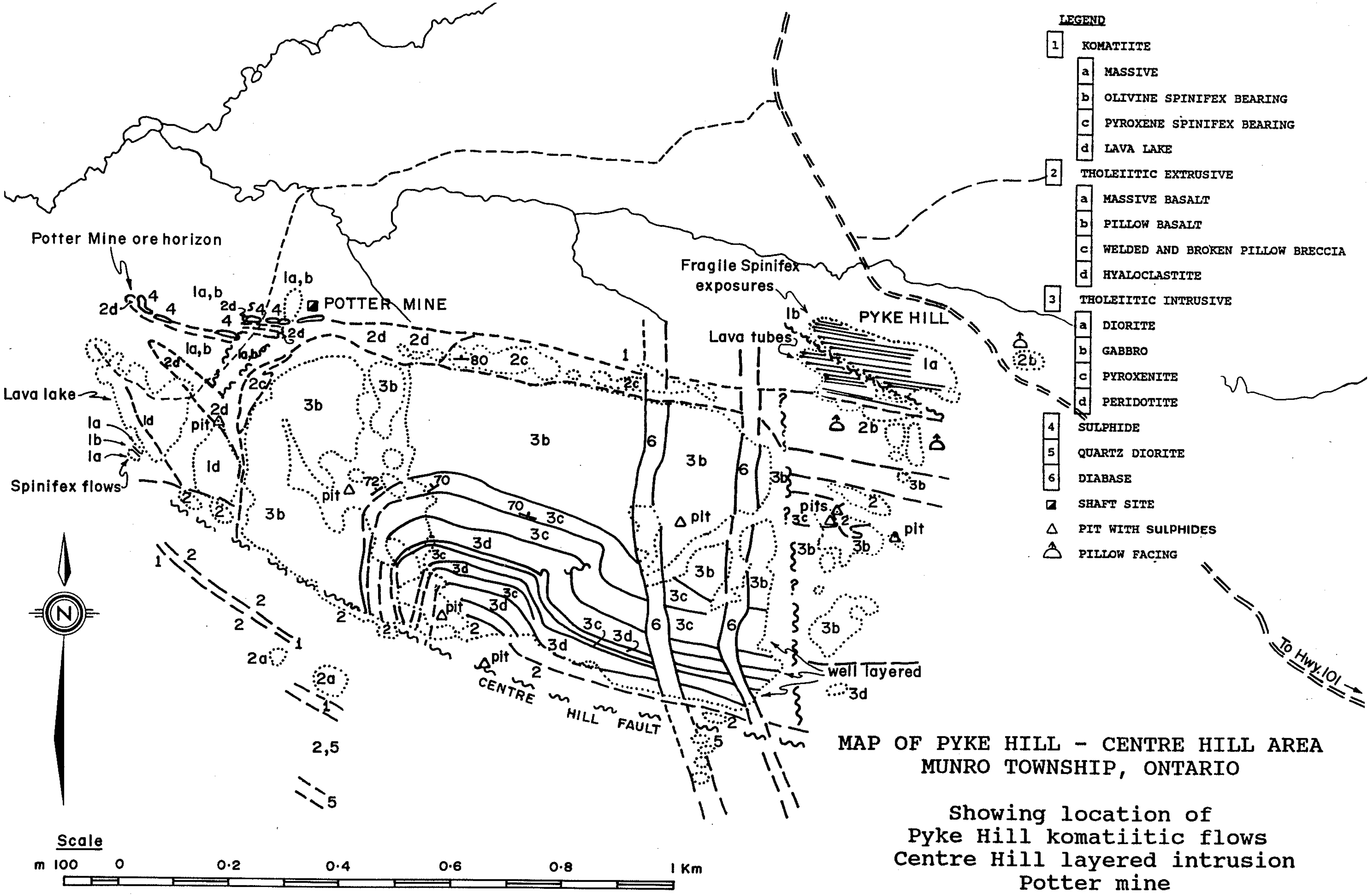


Figure NI1: Generalized geological map of Munro Township (from Arndt and Naldrett 1987).



MAP OF PYKE HILL - CENTRE HILL AREA
MUNRO TOWNSHIP, ONTARIO

Showing location of
Pyke Hill komatiitic flows
Centre Hill layered intrusion
Potter mine
Komatiite Lava Lake

DATA FROM SATTERLY 1952, PYKE et al 1973, COAD 1976, ARNDT 1986

Figure NI2: Generalized geology of the southern part of Munro Township (after Satterly 1951).

komatiitic lava flows described by Pyke et al. (1973) and Arndt and Naldrett (1987). The spectacular spinifex bearing flows are an end member of a continuum from spinifex rich flows to uniform ones in which spinifex is absent. A map of the outcrop is shown in figure NI3. Typical sections through the end member flows are shown in figure NI4. The following description is taken from Arndt and Naldrett (1989).

The spinifex-textured flows consist of:

A1 zone - sparse olivine phenocrysts in a matrix of altered glass. This is the flow top and displays joints (cooling cracks) breaking it up into polyhedra;

A2 zone - skeletal olivine blades become progressively coarser, and are randomly oriented in altered glass with augite needles;

A3 zone - olivine blades develop as randomly oriented books that begin to align at right angles to the flow;

B1 zone - thin zone of tabular skeletal olivine grains;

B2 zone -polyhedral and equant olivine occupies up to 80 percent of the rock with interstitial augite needles and altered glass;

B3 zone - knobby weathering of clots of augite rich matrix is distinctive here, but not common in komatiites outside Munro township;

B4 zone - olivine gives way to altered glass in this basal chill zone of the flow.

More than half of the olivine porphyritic flows on Pyke Hill have no spinifex texture. They are pervaded by polygonal jointing, which is more intense near the flow margins. In the southwest portion of the outcrop lava toes are well exposed. They have massive interiors but their margins are defined by zones of intense polygonal jointing.

6.3.1. Komatiite Lava Lake

Arndt (1986) has described a komatiite lava lake in the centre of Munro Township (Fig. NI5 and NI6) and the following is a summary of his findings. The lava flows face to the north, and the oldest rocks, in the southwest, are normal spinifex-textured and massive komatiites. The lava lake immediately overlies these flows, and is in turn overlain by a thick sequence of mainly mafic pyroclastic rocks. A small deposit in the upper part of the sequence, the Potter Mine, is found in the upper part of the pyroclastic sequence of komatiite flows. These are on strike with the Pyke Hill komatiite flows some 300 metres to the east. On the east side of the lava lake, the volcanic rocks are intruded by, or are in faulted contact with, gabbros from the upper portion of a large layered mafic-ultramafic intrusion called the Centre Hill complex (MacRae 1969). This contact will be described below.

The flows at the top of the sequence are normal spinifex-textured and massive komatiites. They range in thickness from one to thirteen metres and have textures and mineralogies just like those of Pyke Hill, described above. The flow sequence underlying the lava lake is made up of komatiites and pyroxene spinifex-textured basalts.

The lava lake is about 120 metres thick (Fig. NI5). The lower two-thirds is composed of massive, medium-grained dunite, now largely but not completely serpentinized, and upper third is composed of fine-grained olivine porphyry. The upper 30 to 40 metres of the unit are cut by veins with unusual swirling tabular olivines, and in the uppermost 10 to 20 metres numerous spinifex-textured veins appear.

6.3.1.1. Dunite

The dunite is an olivine accumulate. Before serpentinization most samples contained between 70 and 80 percent olivine and minor chromite. Where the olivine grains are not intergrown and do not interfere with one another, most of them are euhedral or distinctly rounded, but a small fraction are more elongate and tabular. Grain size varies from about one millimetre in the lower 20 metres to a maximum of about two millimetres halfway up through the unit. The olivines have relatively uniform compositions, with cores of Fo_{89} and margins of Fo_{88}. Other cumulus phases are chromite, which occurs as relatively large (0.2 millimetre) euhedral grains, and altered orthopyroxene.

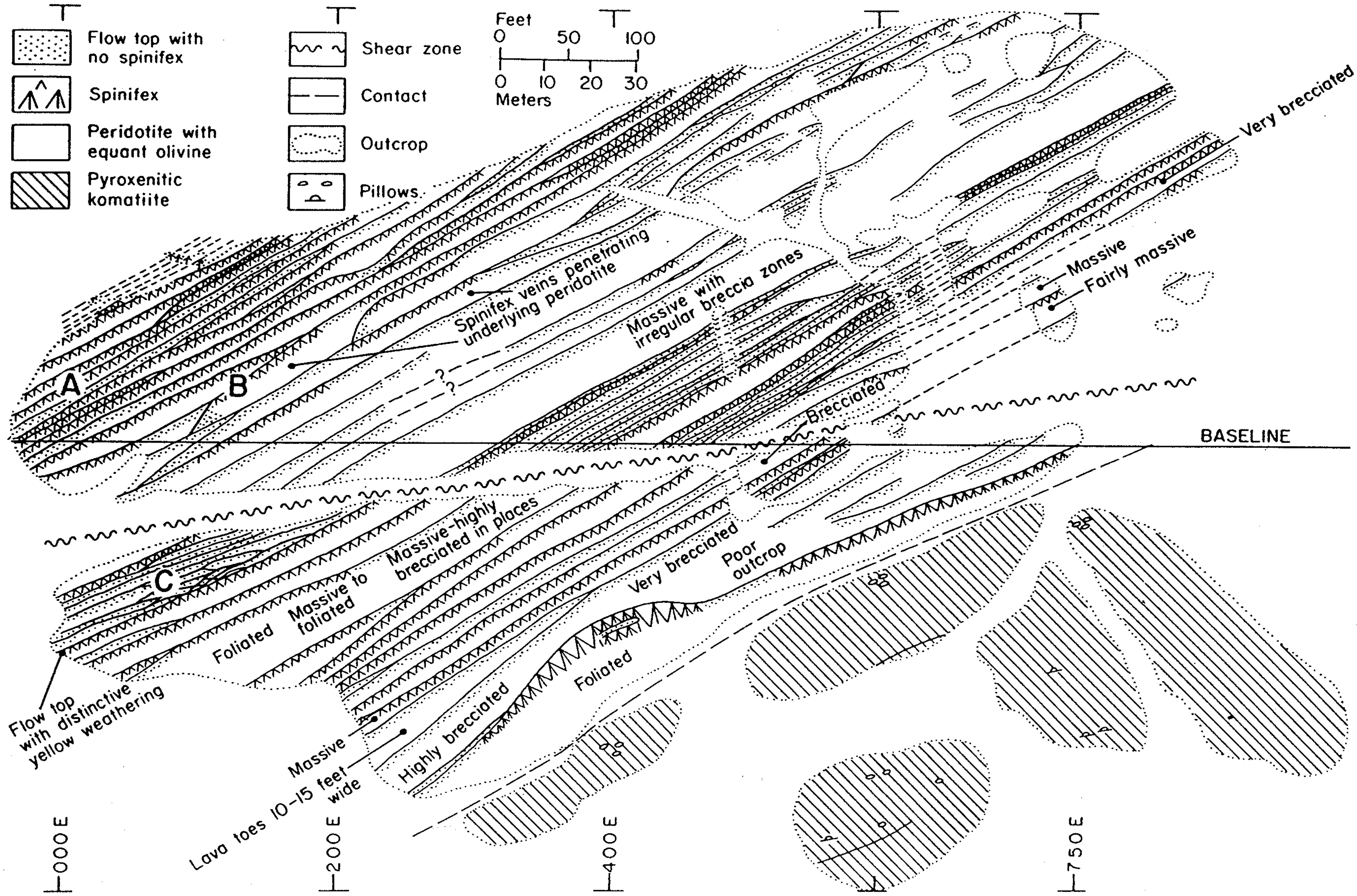


Figure NI3: Geological map of "Pyke Hill", Munro Township (from Arndt and Naldrett 1987, modified after Pyke et al., 1973).

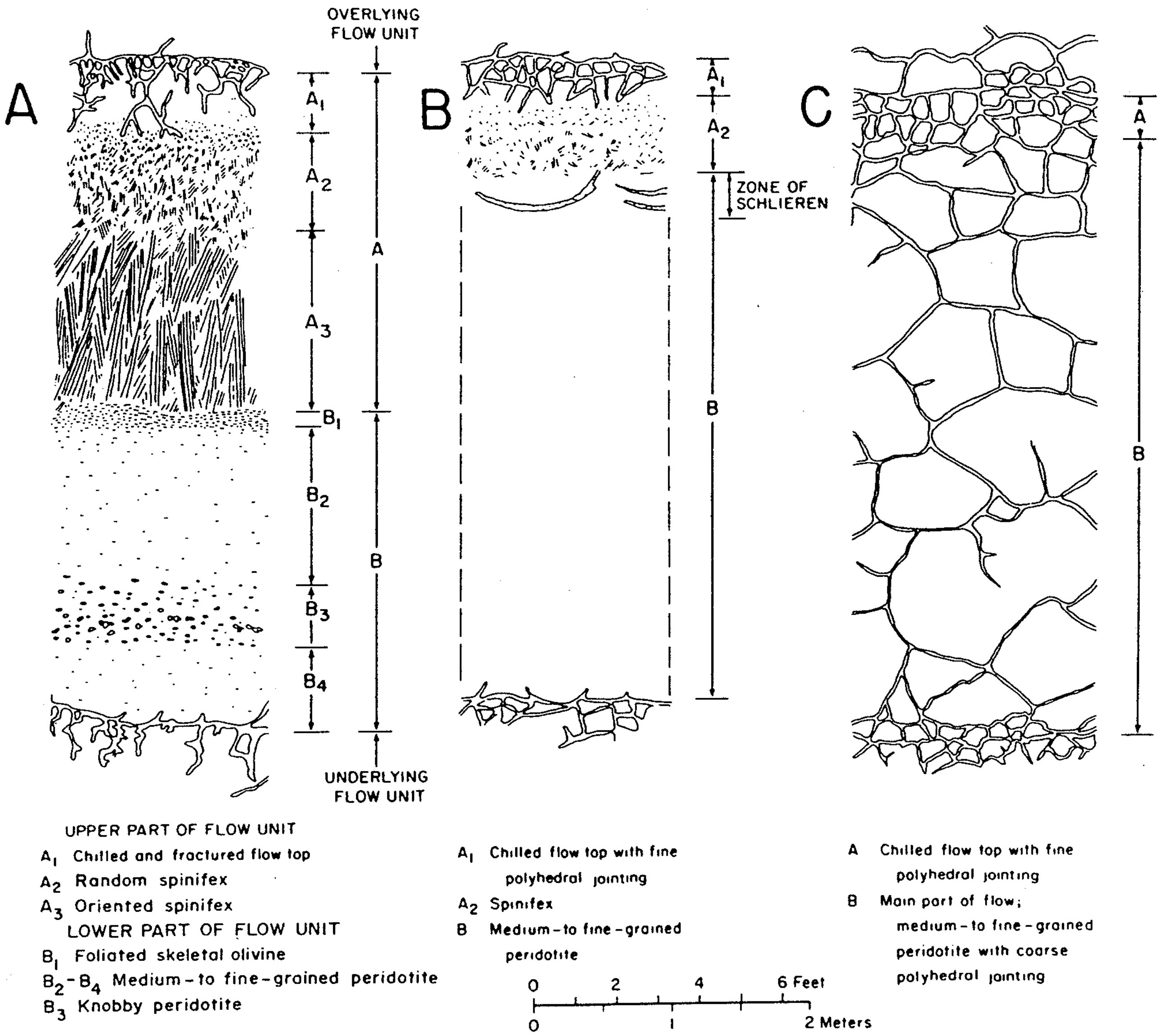


Figure NI4: Typical textural profiles throuth three types of komatiitic flows: A) spinifex-rich flow; B) flow which was quenched after olivine partially settled out and with only minor spinifex texture; C) flow which was quenched before olivine settled and with polygonal joint systems, but no spinifex texture (from Arndt and Naldrett 1987, modified after Arndt et al., 1977).

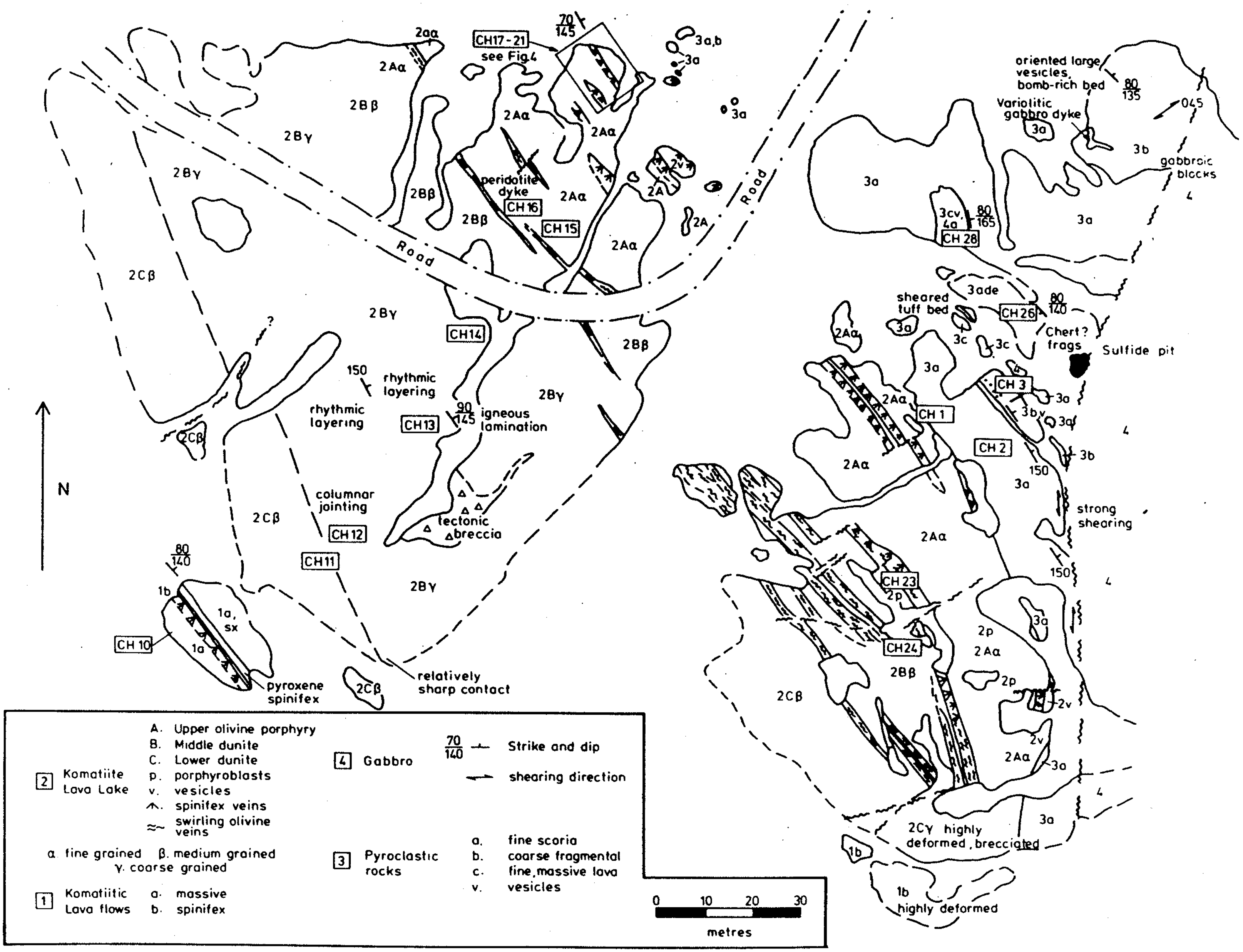


Figure NI5: Geological map showing the main features of the lava lake and surrounding rocks (from Arndt 1986).

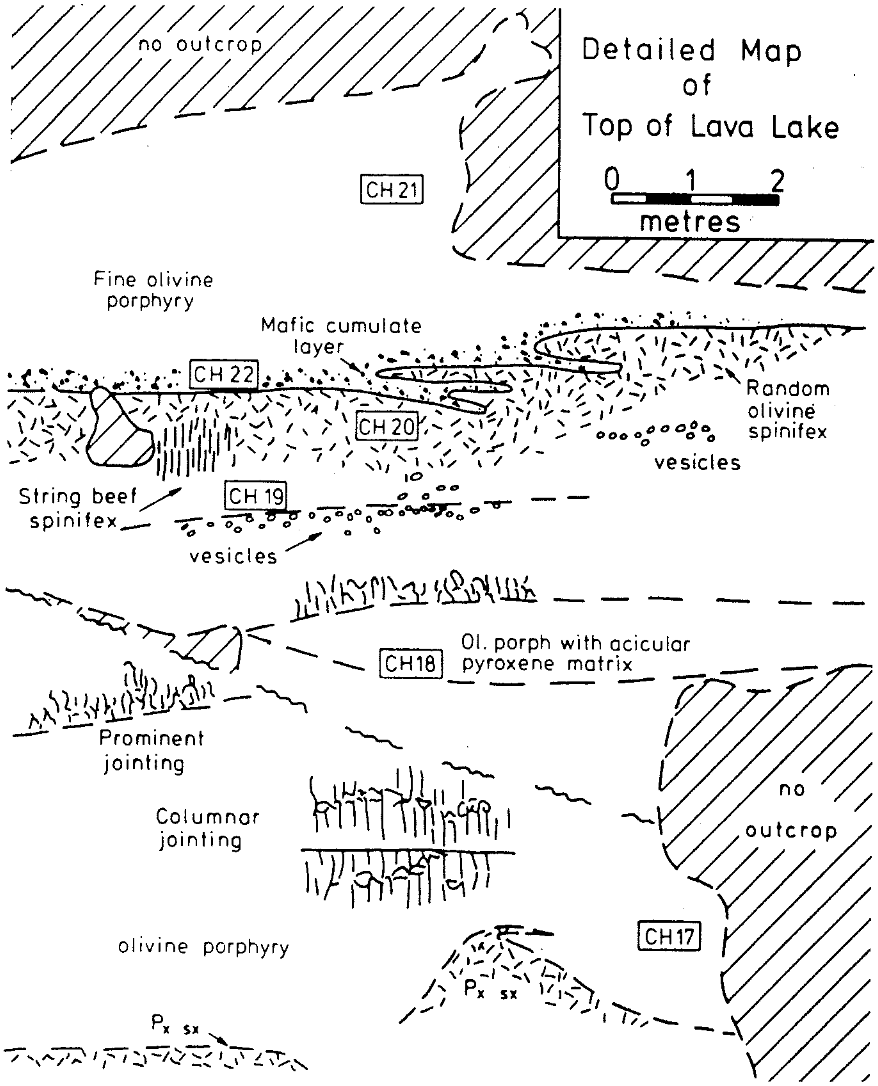


Figure NI6: Detailed geological map of the upper part of the lava lake (from Arndt 1986).

Intercumulus phases are clinopyroxene, plagioclase, brown amphibole and glass, the latter now altered to fine-grained chlorite and tremolite. These phases usually occur as small interstitial grains, but in some samples augite and orthopyroxene (?) form large (upto 6 millimetres) oikocrysts that enclose smaller olivine grains.

Most of the dunitic layer is massive and featureless, but columnar jointing, well-developed igneous lamination and layering at the scale of five to twenty centimetres manifested by variations in grain size, habit or chromite concentration, can be recognized in some places.

6.3.1.2. Structures in the Upper Part of the Lake

In the upper third of the lava lake, olivine grain size is highly variable. Most samples are porphyritic with one to two millimetre olivine phenocrysts in a groundmass containing smaller (0.2 millimetre), equant olivines. Although most phenocrysts are euhedral or distinctly rounded, a relatively large proportion (five to fifteen percent) are elongate and tabular. Phenocrysts have cores of Fo_{88} and are zoned to Fo_{85}; small grains in the groundmass are zoned from Fo_{85} to Fo_{84}. Interstitial phases include augite and bronzite (which have escaped alteration in some samples), plagioclase, brown amphibole and altered glass (Arndt 1986).

6.3.1.3. Spinifex Veins

These are most common in the upper 20 metres of the lava lake where they constitute 10 to 20 percent of the total rock. They range from five centimetres to one to two metres wide, and although some can be traced for tens of metres along strike, others lens out or become increasingly poorly defined and disappear after a short distance. Their orientation is parallel to the upper surface of the lake. Most are composed of fine, random olivine spinifex-textured lava, with patches of parallel 'string-beef' pyroxene spinifex. In many respects, these textures are like those found in the tops of normal komatiitic flows, but there are a number of important differences; a) the upper contacts of the veins are very irregular - rather than being single, horizontal surfaces, the upper contacts meander, interfinger with, or penetrate the overlying lava in veinlets; b) the lower contacts are poorly defined. With decrease in size and abundance of skeletal crystals, the spinifex texture grades downward into the normal olivine porphyritic texture of the host lava; and c) the spinifex texture shows little polarity. The size of the spinifex grains either varies irregularly, or the crystals are finer at both upper and lower contacts, and coarser in the centres of veins (Arndt 1986).

Other structures in the upper part of the lava lake include columnar jointing, metre bands of amygdules, and layers enriched in mafic minerals. The ultramafic bands are interpreted as cumulates enriched in olivine and one or two pyroxenes (Arndt 1986).

6.3.1.4. Swirling Olivine Veins

These remarkable veins are found in the interval from 20 to 40 metres from the top of the unit. They contain 50 to 70 percent tabular olivine grains and have a swirling fabric that mimics, on a macroscopic scale, trachytoid textures seen in thin sections of many feldspar-rich volcanic rocks. Tabular olivines are oriented parallel to one another on a small scale, but this orientation varies tremendously to produce kinks, swirls, and tight, incoherent folds. Margins of the veins are sharp with no sign of chilling. At the borders, the orientations of olivine grains are more regular and parallel to contacts (Arndt 1986).

The olivine grains are tabular and essentially euhedral, but with distinctly rounded edges. Most are about one to two millimetres long and 0.1 to 0.2 millimetres wide. In all samples, olivine is completely replaced by chlorite or serpentine and its composition could not be measured. Interstitial minerals are the same as in the olivine porphyries - clinopyroxene, orthopyroxene (?), chromite, and altered glass. In some cases clinopyroxene forms oikocrysts, and their orientation is not always the same as that of adjacent tabular olivines. This observation is important, because it indicates that the clinopyroxene oikocrysts were present while the lava was flowing, and while olivines were continuing to grow. It follows that the veins must have formed from liquid with clinopyroxene and olivine as liquidus phases (Arndt 1986).

6.3.2. Centre Hill Complex

The Munro Lake sill, according to MacRae (1969), is a grossly layered intrusion exposed in three principal areas: Centre Hill, McCool Hill, and a broad area at the boundary between Warden and Munro townships. The body is indicated to be continuous by aeromagnetic maps, and the stratigraphic sequences or rock layers in the three principal sections are strikingly similar. The sill is approximately 11 kilometres in length and 500 to 1000 metres thick. It is folded along a major east-west syncline having almost vertical limbs, and is complexly broken by both longitudinal and cross faults. Minor folds are common on both limbs, especially between Centre Hill and the Warden-Munro areas.

The Centre Hill outcrop area is the only one showing a complete stratigraphic section of the Munro Lake sill between its lower and upper contacts. Within the exposure at Centre Hill, the intrusion is essentially vertical. It generally has an east strike, but it is folded sharply southward at its western end where MacRae (1969) interpreted it to be dragged against and cut off by the Centre fault (Fig. NI2). Both the northern and southern (or upper and lower) contacts of the sill with volcanic rock are exposed. On the north it has intruded a mafic fragmental rock and on the south, basalt. The contacts are sharp and at places there is a slight intertonguing of the intrusive and volcanic rocks. Immediately adjacent to the lower contact, the intrusive rock may have been slightly chilled, but an exact interpretation is difficult because of the subsequent metamorphism and alteration of the rock.

The following description of the Complex is provided by Coad (1976). "The complex is not a simple layered body, but is composed of many alternating layers of ultramafic and mafic rocks. MacRae (1969) recognizes seven cyclic units. The lower five consist of successive layers of peridotite and clinopyroxenite, the sixth is composed of clinopyroxenite and gabbro and the upper most seventh unit consists of a layer of melanocratic gabbro overlain by normal gabbro. The ultramafic layers range in thickness from one to fifty metres and lie in sharp contact with each other. The uppermost gabbroic unit is over 200 metres thick.. At the lower contact there is a unit of hornblendite ten to thirty metres thick."

The uppermost gabbro unit is overlain by a fragmental rock which is best described as a pillow breccia. This particular rock unit was previously mapped as a rhyolite agglomerate (Satterly 1951); however, it has a composition intermediate between a tholeiitic olivine basalt and picritic basalt. The contact between the pillow breccia and gabbro appears to be faulted where examined in aerial photographs and is seen to be sheared where exposed. The pillow breccia outcrops over a stratigraphic thickness of approximately 60 metres. Drill hole information, together with extrapolation of rock unit thicknesses along strike, indicate that this thick unit of fragmental rock is approximately 75 metres thick in the east, but becomes progressively thinner towards the west, along strike. The eastern extension of the pillow breccia is not exposed because of extensive drift cover and major north south faulting along the eastern edge of the Centre Hill complex. Pillow breccia is stratigraphically overlain by komatiitic lava. To the west outcrop exposure of the pillow breccia is not continuous along the top of the Centre Hill complex, but drill hole data, together with outcrop exposure further to the west, indicates that this rock unit grades laterally along strike into hyaloclastite (Coad 1976).

6.3.3. Potter Mine

The Potter mine is located in the central portion of Munro township immediately north and west of the Centre Hill complex (Fig. NI1). Arndt (1975) suggests that this complex, a large differentiated peridotite/gabbro body, lies on the southern limb of the major west plunging synclinal structure referred to previously, and that it may be correlated with Theo's flow on the northern limb of the same structure. The Centre Hill complex compares in some respects with Theo's flow. However, the hyaloclastite which forms a cap to the Centre Hill body grades westward along strike into pillow breccia. Hyaloclastite is not restricted to the top of the complex but intertongues with komatiitic lavas forming three discrete horizons further to the west. The aphanitic pyroxenite member of Theo's flow is absent from the Centre Hill complex; instead a massive, ropy, brecciated, quench-textured tholeiite commonly occurs between the hyaloclastites and the gabbro forming the top of the underlying complex. A further difference is that the complex consists of a number of cyclic mafic and ultramafic units in contrast to the continuous progression of Theo's flow (Coad 1976).

It seems a curious coincidence that the mine overlies the junction of the Centre Hill complex to the east and the Komatiite lava lake to the west. The zone of shearing between these was always assumed to be a fault by MacRae (1969) and others. However the excellent mapping, drill core logging and petrography described by Coad (1976), which is referenced extensively in this section, permits another interpretation. He shows that the hyaloclastite and the mineralized horizons of the Potter Mine lie at the same levels without offset either side of the shear zone. Although some faulting undoubtedly did occur, part of it may have been synvolcanic, and the zone is an excellent candidate for a feeder zone for the mineralization. It is quite possible that the lava lake and the Centre Hill sill or flow lie close to their original positions and represent a facies change.

6.3.3.1. Mine History and Geology

The copper at the Potter Mine was first investigated in the 1920's. In 1952 the Centre Hill Mines Ltd. commenced exploration that included 12,190 metres of drilling in 1956. In 1957 a shaft was sunk to 125 metres. The deposit came under the control of Zenmac Metal Mines Limited in 1959 and in 1964 underground exploration resumed. In 1967 production commenced from a shaft deepened to 295 metres, using an on site mill rated at 710 tonnes per day. The mine was sold to the Patrick Harrison Company Limited in 1969 and closed in 1972.

Between 1967 and 1972, 485,210 tonnes of ore were milled at an average grade of 1.63 percent Cu, 1.5 percent Zn, 3.1 to 15.5 g Ag/tonne and traces of gold.

The following descriptions are directly taken from Coad (1976). "The mine geology is characterized by two distinct volcanic series, namely komatiitic lavas and tholeiitic olivine basalts. The komatiitic lavas consist predominantly of picritic flows and intercalated with these flows are massive peridotitic komatiites, characterized by an MgO content greater than 30 percent. The massive peridotitic komatiites are not characterized by associated flow tops marked by spinifex texture. The tholeiitic and olivine basalts are chemically distinct from the komatiitic lavas and consist of three different rock types: 1) hyaloclastite; 2) quench-textured tholeiite; and 3) pillow breccia. Although volumetrically insignificant, thin beds of volcanic ash occur at the top of the hyaloclastite horizon and actually represent a third distinct rock sequence, having a dacitic composition."

The predominant rock type in the central portion of the map area is hyaloclastite, a term used to describe a fragmental consisting of pea-sized fragments of pillow breccia and glass (Coad 1976). The hyaloclastite is commonly stratigraphically underlain by quench-textured tholeiitic lava which outcrops over a stratigraphic thickness of approximately 12 metres. The hyaloclastite matrix can consist of ash and fine grained carbonate, quartz, plagioclase and up to 19 percent disseminated graphite (Coad 1976). Volcanic ash occurs at the top of the hyaloclastite units. This ash is composed of grains of quartz and broken plagioclase crystals and it locally is banded and shows load-cast structures (Coad 1976). Thin layers (<0.5 metres) of chert also occur within the ash unit (Coad 1976). The hyaloclastite and quench-textured tholeiite form a wedge-shaped mass at the western end of the Center Hill complex which have been drag-folded and down-faulted stratigraphically into place, or, may have formed approximately in their current position (Coad 1976).

Coad (1976) provides the following description of the pyroclastic rocks in this area. "The pyroclastic sequence contains a lower portion of crudely-bedded, well-sorted basaltic scoria and an upper portion of coarser agglomerates and welded spatter, also with basaltic composition and also crudely bedded or massive. Fragments in the scoria average 0.5 to 1 millimetres across. Most are approximately equidimensional, with shapes varying from subangular to rounded, to amoeboid or ribbon-like. Some smaller grains in the matrix have shard shapes. Textures vary considerably, from originally completely glassy (now altered to chlorite), to fine-grained porphyritic with small, altered olivine and clinopyroxene phenocrysts, and in rare cases microspinifex. Most fragments are not amygdaloidal or contain only sparse amygdules (1 to 2 percent), but some fragments have 10 to 15 percent. Amygdules are less than 0.5 millimetres across. One or two fragments in each thin section have a wispy, patchy, ribbon-like form and may be squashed pumice. Each thin section also contains a few, usually larger, angular fragments of exotic rock types such as feldspar-porphyritic felsic volcanics, pale cream relatively pure cherts, and dark-coloured graphite- rich (?) cherts. The matrix is cryptocrystalline cherty quartz, feldspar and chlorite, or carbonate."

"The agglomerates higher in the unit have fragment sizes between one and fifty centimetres, usually around two to five centimetres. Fragments are rounded or have complex amoeboid shapes. They are commonly deformed and moulded against adjacent fragments. They also have basaltic composition and fine grained aphanitic or olivine-clinopyroxene porphyritic texture."

6.3.3.2. Mineralization

Massive and matrix sulphide mineralization at the Potter Mine consists predominantly of pyrrhotite, equal proportions of sphalerite and chalcopyrite, and minor pyrite (Coad 1976). Economic concentrations of sulphide mineralization are restricted to the hyaloclastite horizon, but sulphides were remobilized along shears into the adjacent picritic basalt flows (Coad 1976). Iron-rich sphalerite occurs throughout the hyaloclastite horizon, associated with chalcopyrite and pyrrhotite. Iron-poor sphalerite occurs at the top of the hyaloclastite horizon (Coad 1976).

Matrix sulphide is the more common habit, whereby sulphides occupy the interstices between fragments of glass, pillow breccia of the hyaloclastite (Coad 1976). The matrix or disseminated sulphide grades into massive sulphide lenses. Massive ore lenses occur within the upper hyaloclastite horizon, although some massive ore may also have occurred in the lower hyaloclastite (Coad 1976). These lenses, ranging from 15 to 30 metres in length, lie directly on top of the hyaloclastite horizon. The massive sulphide lenses average one metre in thickness, but are continuous in the vertical dimension to a depth of 365 metres (Coad 1976). The massive sulphide lenses were commonly banded with respect to chalcopyrite, sphalerite, and pyrrhotite (Coad 1976).

The massive sulphide is intimately related to volcanic ash which occurs throughout the hyaloclastite unit, but which is more abundant at the top of the unit (Coad 1976). The upper surface of the massive sulphide lense lies in sharp contact with the chilled base of the overlying picritic (komatiitic) flows (Coad 1976). A thin concentration of iron-poor sphalerite may occur along this upper contact (Coad 1976).

Coad (1976) did not observe stringer mineralization. However, stringer mineralization, associated with chlorite alteration, was reported to occur in an area of the mine that was disrupted by shearing (Coad 1976, p.144). Chlorite also occurs as a matrix mineral where the hyaloclastite is sheared or mineralized with sulphides (Coad 1976).

6.3.3.3. Metal Zoning

Despite the abundance of komatiites in this area, the sulphide mineralization did not contain significant nickel, and averaged only 0.03 weight percent (Coad 1976, p. 172). The copper/zinc ratio was close to or less than one (Coad 1976), although the massive ore was zoned from a zinc-rich top to a copper-rich base (Coad 1976). Zinc grades were much less in the vicinity of the strong chlorite alteration zone, supporting the premise that the chlorite alteration represented a feeder-pipe (Coad 1976). Nickel/cobalt ratios of the ore were less than one (Coad 1976).

6.3.3.4. Genesis

According to Coad (1976), the source of metals concentrated in that mine is probably the mafic-ultramafic magma represented by the Centre Hill Complex, in particular the gabbro member. The metals were probably transported either by primary hydrothermal fluids escaping during magmatic differentiation or by secondary leaching involving the convection of sea water. Whether or not sea water penetrated the gabbro, a combination of solutions was probably instrumental in the transportation of metals from the gabbro member of the Centre Hill complex through the overlying hyaloclastite units. The sulphur may have been derived from both sea water and the magma (Coad 1976).

6.4. **Alexo - Dundonald deposits**

6.4.1. Regional Setting

Three nickel deposits associated with komatiites lie east of Timmins in Dundonald Township (Fig. NI7): 1) Alexo; 2) Dundonald; and 3) Frederick House (FH) Lake deposits. The stratigraphy in this area is not well established and is known mainly by correlation with the better studied and exposed rocks in the Munro Township area. The reader is referred to Section 4.3 of this field guide for more information on this subject, including references. The stratigraphy here is part of a traceable belt extending for more than 100 kilometres from Munro Township to the Kidd Creek area. Further west and east than this, continuity is difficult to establish.

6.4.2.1. History

The following is a brief history of the property development:

1951: Magnetic survey by Quebec Asbestos Corporation;

1951: Geological Survey by Dominion Gulf;

1955: Diamond Drilling (403 metres) by Consolidated Mattarow Mines;

1960: Geophysical and geological surveys were conducted by Falconbridge Limited. They concluded that ultrabasic rocks on the property were favourable sites for Alexo type nickel deposits, even though sulphides in the trenches contained insignificant amounts of base metal;

1962 From this date on Falconbridge Limited conducted several exploration programs that discovered, and then evaluated the Dundonald deposit.

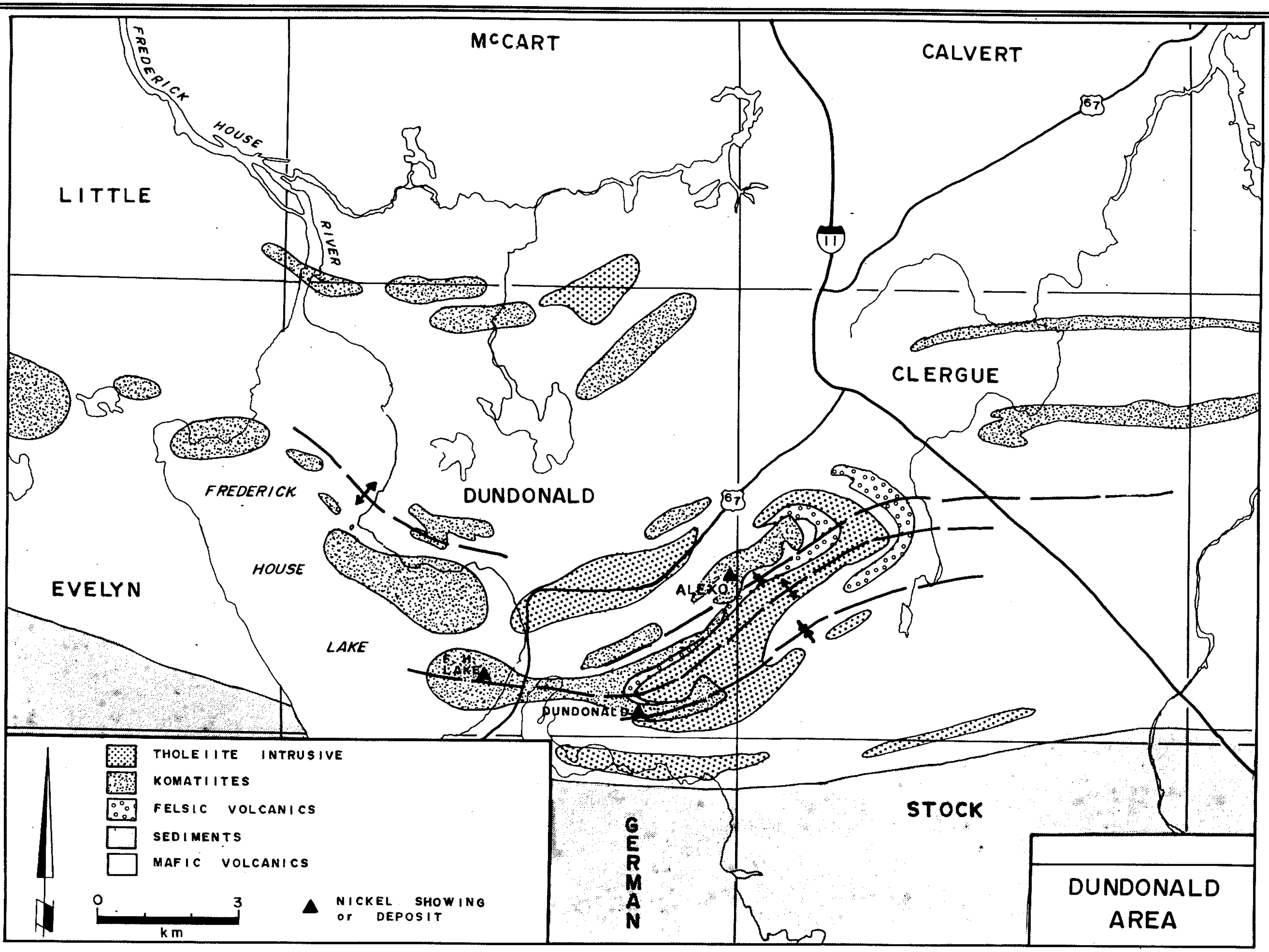


Figure NI7: Generalized geology of the Dundonald area, illustrating the location of the Alexo, Dundonald, and Frederick House (FH) Lake komatiite-associated, nickel sulphide deposit.

6.4.2.2. Geology

The geology of this area has been described by Naldrett (1964), Naldrett and Mason (1968) and Muir and Comba (1979). The area is underlain by mafic to felsic metavolcanic rocks, which were intruded by the Dundonald Sill, a layered tholeiitic, peridotite-gabbro intrusion. Ultramafic flows are an intimate part of the volcanic stratigraphy. At least six peridotitic komatiite flows, collectively up to 200 metres thick, occupy the two limbs of the syncline. This series of continuous ultramafic flows, termed the "overlying lenses" (Naldrett 1964), conformably overlies the felsic metavolcanic and metasedimentary rocks. Spinifex texture in the komatiites is well developed and is clearly seen in the drill core. The Dundonald deposit is located in the Number 5 lens.

6.4.2.3. Structure

The structure of the area is complex and remains debated. The rock sequence appears to be folded into a syncline (Kilburn et al. 1969) and the distorted W-shape of the sill, illustrated by the magnetic patterns, was attributed to this fold (Naldrett 1964). Therefore, the Dundonald Sill is interpreted to have been intruded before the main folding of the area (Naldrett 1964). The second limb of this syncline was only recently recognized as the new mineralized zone, discovered in 1969. Subsequently, a considerable amount of detailed mapping was conducted by Falconbridge Limited on the property between 1970 and 1974. Muir and Comba (1979) concluded that the sequence of ultramafic metavolcanic rock, which is host to the mineralization at Dundonald, was part of a homoclinal sequence lying on the south limb of the Dundonald anticline. The W-shape, defined by magnetic patterns, was attributed to faulting of the Dundonald sill after its emplacement. Diamond drilling in 1989 tested the entire sequence of ultramafic and intermediate metavolcanic rocks at Dundonald and no evidence for north-facing tops was found. This absence of north-facing tops argues against the presence of a synclinal fold in the area, and supports the interpretation of Muir and Comba (1979). It should be noted that the south contact between the metavolcanic rock and the intrusive sill is a faulted one. Therefore, the possibility still exists that a fold structure may be present, but that it has been faulted off at depth.

The core of the synformal structure contains the Number 2 pyroxenite and a series of mafic to intermediate metavolcanic rocks which lie along the synformal axis.

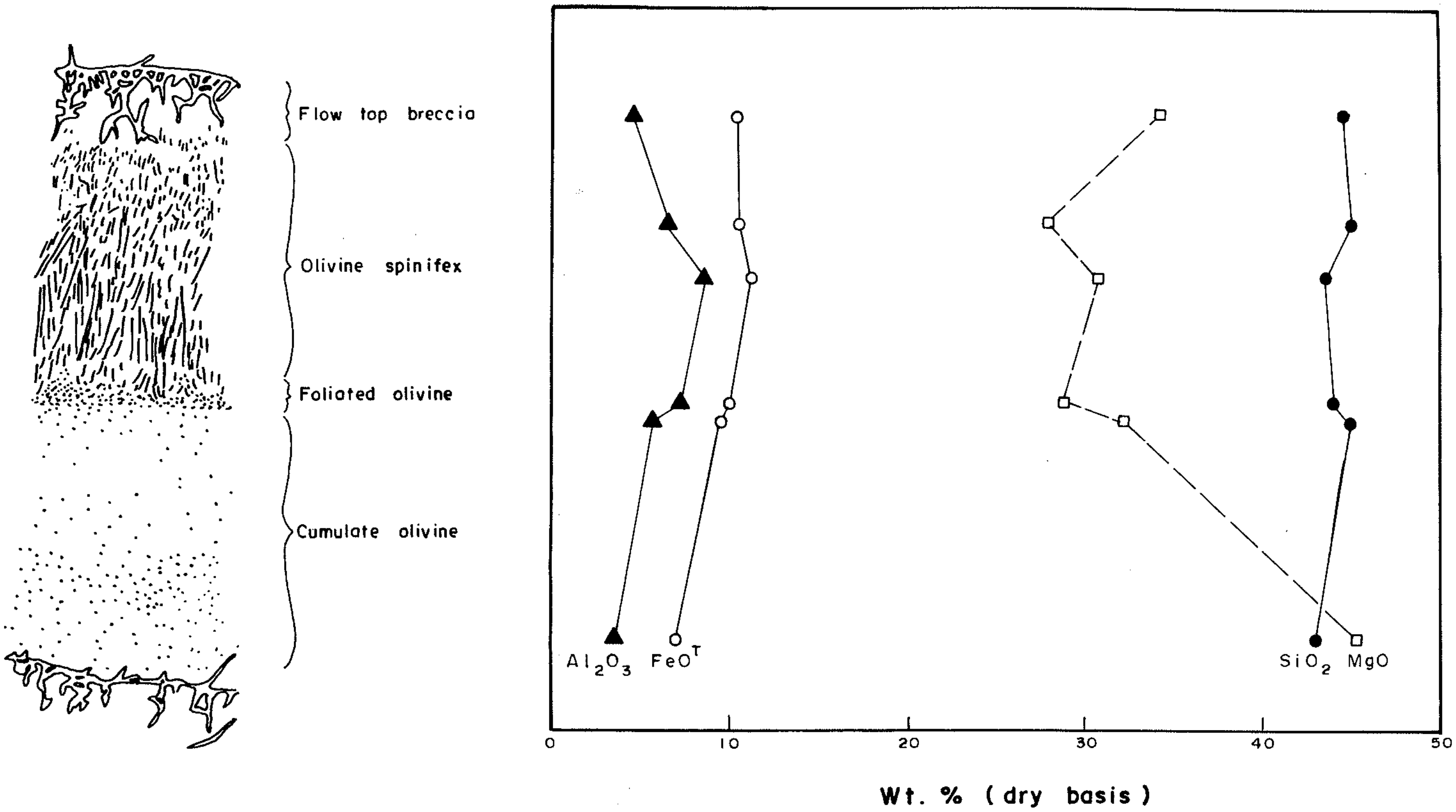
6.4.2.4. Petrology of the Komatiites

The peridotitic komatiite flows are petrologically very similar to those described from Munro Township (e.g., Pyke et al. 1973). Olivine meso-adcumulate consists of 80 to 90 percent euhedral, equant, serpentinized olivine grains up to three millimetres in diameter. Interstitial material consists of skeletal and plumose clinopyroxene grains or subhedral to acicular partly amphibolitized clinopyroxene, prismatic to equant colourless garnet, chlorite and quartz. Euhedral chromite and secondary magnetite are commonly present, especially where serpentinization is very strong. A typical cross-section of one of these flows at Dundonald, along with the variation of some major elements, is illustrated in figure NI8 (after Muir and Comba 1979).

Pyroxene spinifex consists of hollow, zoned clinopyroxene needles in devitrified glass. This spinifex-bearing zone, up to four metres in width, is stratigraphically overlain by a komatiitic peridotite flow. A quenched flow top is commonly observed above the spinifex zone. This type of spinifex has been termed "string-beef" spinifex (Arndt et al. 1977). The spinifex grades down into a section of acicular and plumose clinopyroxene. It grades into a gabbroic-textured zone comprised of greenish plagioclase laths surrounded by ophitic clinopyroxene. This zone may grade down into an olivine orthocumulate, depending on the original composition of the flow. A typical cross-section of a pyroxenitic flow at Dundonald, along with the variation of some major elements, is illustrated in figure NI9.

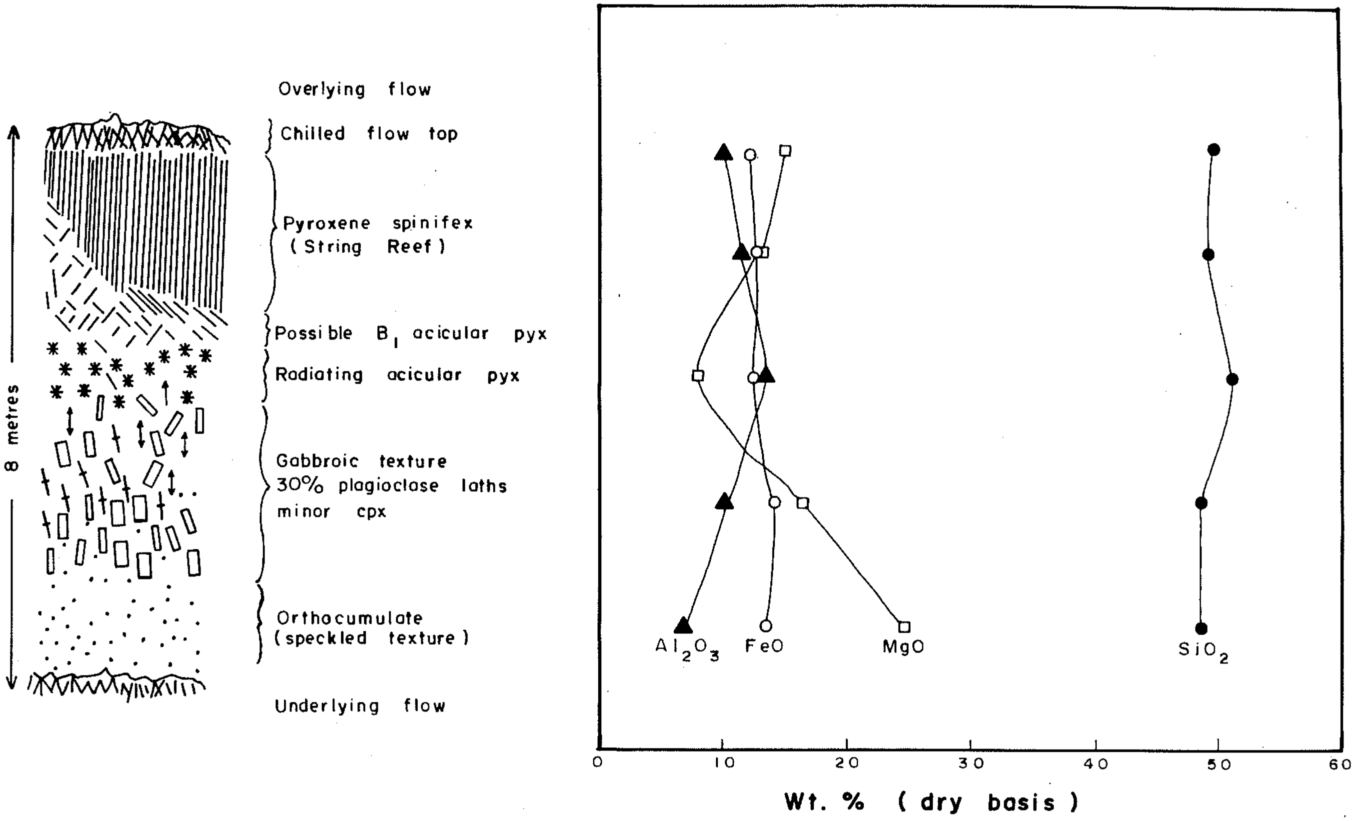
The komatiitic rocks at Dundonald are distinguished from tholeiitic rocks of the Dundonald sill using an Al_2O_3 vs. (Fe_2O_3/MgO + Fe_2O_3) diagram (Fig. NI10).

Between most of the komatiite units, carbonaceous units and bands of volcano-sedimentary material occur, including layered, cherty lapilli tuff and carbonaceous, pyrite-bearing metasediment.



Variation of major elements within a typical peridotitic flow.

Figure NI8: Variation of some major elements across a peridotitic komatiitic flow from the Dundonald area.



Variation of major elements within a typical pyroxenitic flow.

Figure NI9: Variation of some major elements across pyroxenitic komatiitci flow from the Dundonald area.

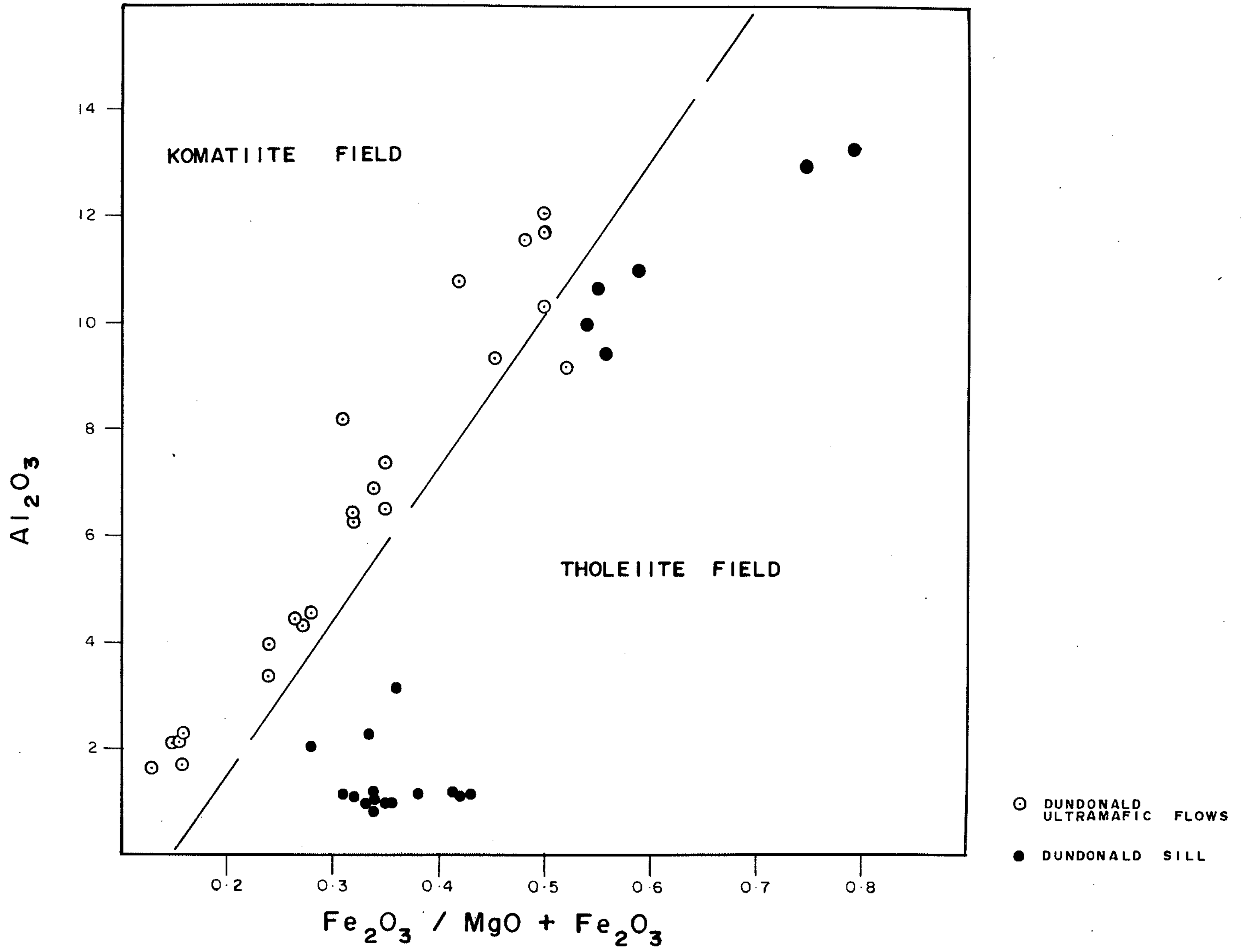


Figure NI10: Discrimination between komatiitic flows and tholeiitic rocks of the Dundonald sill at Dundonald, using an Al_2O_3 vs. (Fe_2O_3/MgO+Fe_2O_3) diagram.

6.4.2.5. Mineralization

The mineralization at Dundonald consists of three types associated with the ultramafic flows:

1) Massive stringers or nodules of pyrrhotite and pyrite and very fine and disseminated pyrrhotite in the graphite bands. Some of the graphite bands extend into the metavolcanic rocks which underlie the ultramafic flows.

2) Fine disseminated pyrrhotite (2 to 5 percent sulphides), most of which occurs in the basal cumulate part of the ultramafic flows;

3) Sulphide stringers or disseminated nodules which occur in the dark green serpentinized peridotite.

The mineralization at Dundonald is comprised of at least four distinct mineralized horizons, the A, B, BN, and C Zones. A fifth zone (#5) is possibly correlative to the deeper C Zone. There are three main mineralized zones on each limb of the syncline. The bulk of the mineralization is confined to the B Zone which is located in the center of the stratigraphically uppermost unit of peridotite flows. The mineralogy of the deposit consists of pyrrhotite, pentlandite, pyrite and minor amounts of millerite, godlevskite, heazlewoodite, gersdorffite, sphalerite and chalcopyrite.

The #5 zone was exposed at surface (surface stripping program) and is located at the stratigraphic base of the lowermost peridotite. The mineralization, as exposed at surface, is disseminated to massive. It is commonly shear bounded and, consequently, is discontinuous. Remobilized and fracture-filling nickel sulphide mineralization is exposed on surface. It consists of bravoite, a mineral formed by the replacement of nickel for iron in pyrite, or the replacement of iron for nickel in pentlandite.

It appears that the style of nickel sulphide mineralization varies with respect to its location within the flow (Fig. NI11). Massive and disseminated sulphide mineralization appears to be located at, or very near, the base of the thicker peridotite units. The stringer, nodule and disseminated sulphide mineralization, associated with graphite in fractures, occurs in ultramafic hyaloclastite flow top units.

6.4.2.6. Tour Stop

Surface stripping was completed over part of the Dundonald deposit during 1989. This outcrop will be visited by the field trip. The outcrop was geologically mapped at 1:100 (Fig. NI12) and rock types were lithogeochemically sampled. Mapping of the stripped area revealed that the stratigraphy is comprised of a series of steeply dipping, south-facing, pyroxenitic and peridotite komatiitic flows which unconformably overlie the Dundonald Sill. Three main pulses of peridotitic komatiite volcanism are separated by magnesium-rich tholeiitic basalts and pyroxenites. Each major pulse of volcanism is comprised of several, thin, individual flows which are separated by interflow graphitic sediments. Spinifex textures in the pyroxenites and peridotites are well preserved and define south-facing tops. The contact is faulted and generally quite graphitic. An intermediate to mafic metavolcanic unit is commonly found along the contact between the Dundonald Sill and the ultramafic flows. Each major pulse of pyroxenite or peridotite consists of several thin, discontinuous flows. Flow tops are generally marked by thin sulphide-rich units of carbonaceous material and/or variable amounts of chilled volcanic fragments of intermediate, mafic and ultramafic compositions.

6.4.3. **Alexo Deposit (Dundonald Township)**

The Alexo deposit is located in southeast Dundonald Township, 50 kilometres southeast of Timmins. Access is by a short gravel road from Highway 67. It is currently owned by Noranda Mines Limited.

6.4.3.1. History

The following is a brief history of the property development:

1907: Discovered by Alex Kelso;
1912-19: Mined by Alexo Mining Company. 52,000 tonnes of 4.5 percent Ni and 0.5 percent Cu. Production ceased in 1919;
1943-44: Harlin Nickel Mines Limited. Recovered several thousand tonnes of Ni;
1952: Ontario Nickel Mines Limited. Nickel sulphide concentrations deemed uneconomic;
1958: Noranda Mines Limited. 15 diamond drill holes also failed;

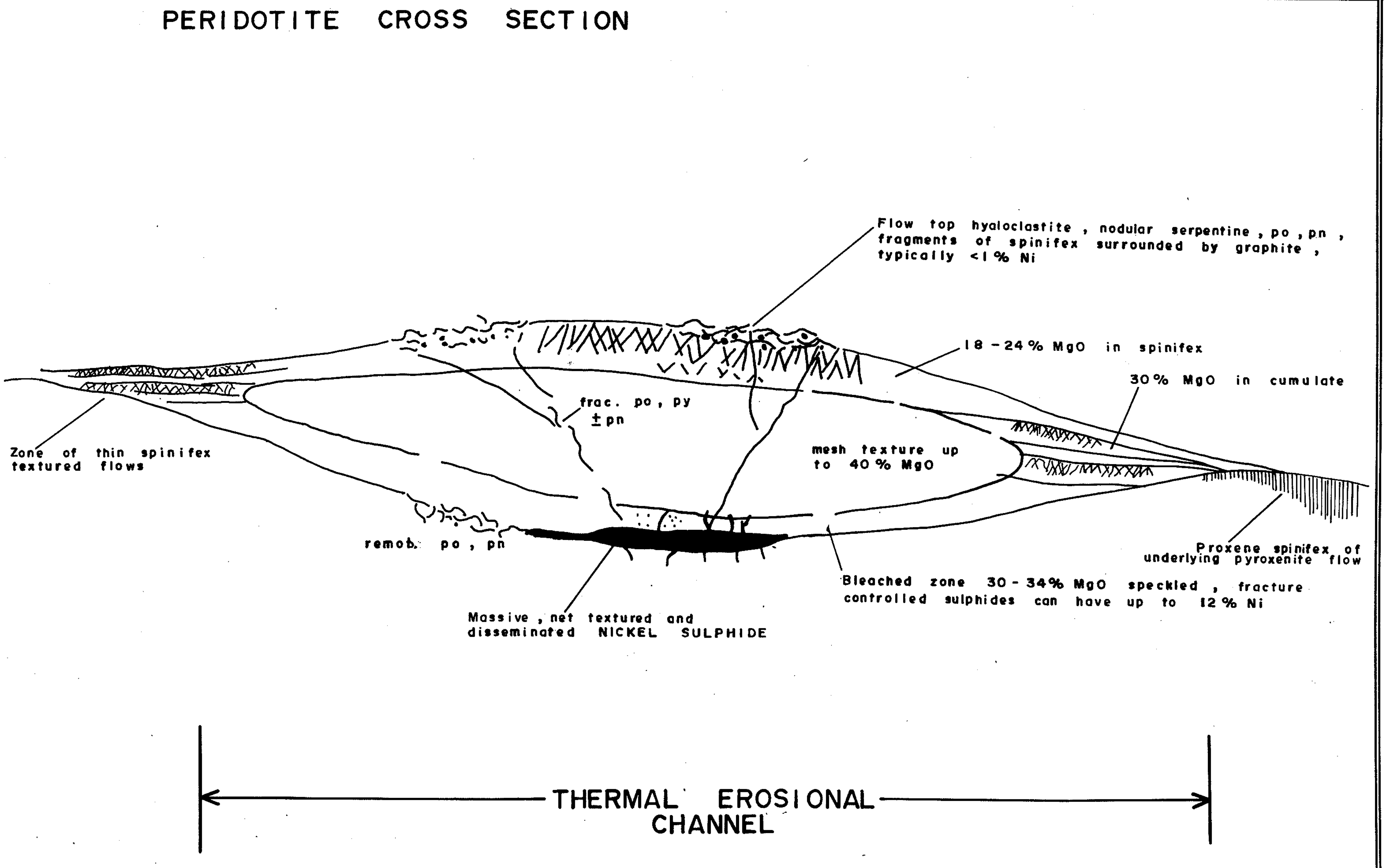


Figure NI11: Schematic cross-section through an ultramafic komatiitic flow, illustrating the variation in nickel-sulphide textures.

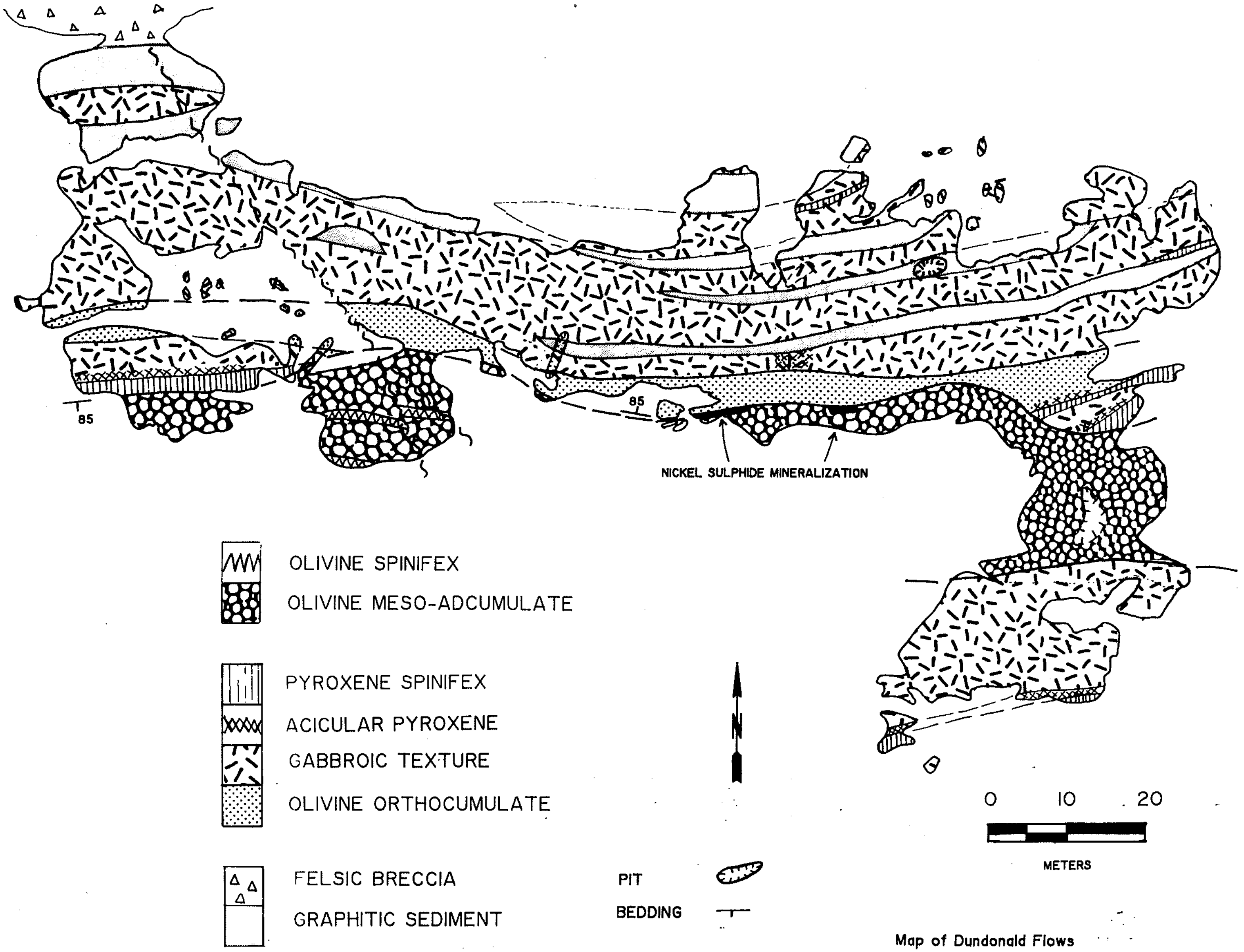


Figure NI12: Detailed geology of the Dundonald nickel-sulphide deposit area.

1976: Noranda Mines Limited. Ground magnetic survey.

6.4.3.2. Geology

The Alexo deposit occurs in a concordant ultramafic lens, which has a dunitic core and pyroxene-rich peridotite margins. This ultramafic lens is correlative with pyroxene-rich lenses which occur in pillowed metavolcanic rocks to the west, stratigraphically above the Dundonald Sill. The footwall rocks are pillowed basalts, interlayered with hyaloclastites and spinifex-bearing komatiitic flows. The deposit occurs in a footwall embayment, about 90 metres long, which dips vertically at the surface, but 70° to 80° to the north at depth. The embayment ranges from 1 to 12 metres in width. Massive pyrrhotite and pentlandite occur along the contact and vary from five centimetres to three metres in thickness. The sulphide mass lies in sharp contact with overlying, net-textured sulphides. Massive sulphides penetrate up to five metres into the metavolcanic footwall. Ore minerals consist of pyrrhotite, pentlandite, magnetite and chalcopyrite. The sulphide minerals commonly replace olivine and/or pyroxene grains. Sulphides that have pseudomorphed olivine spinifex have been identified.

During the early phase of mining, up to 1919, approximately 52,000 tonnes of nickel was produced. Several thousand additional tonnes of nickel were recovered in 1943.

6.5. **Shaw Dome**

South of Timmins the main structure is a north-west trending dome, apparently 20 kilometres long by 12 kilometres across, centred in Shaw Township. The eastern periphery of a second dome is partly exposed in the southwest corner of the area in McArthur and Bartlett townships. The emplacement of the Kenogamissi batholith complex has destroyed most of the western portion of this second inferred domal structure. These domal structures are interpreted to outline former volcanic centres. Facing directions are generally outward except where folding, near the dome margins, produced both Z- and S-folds. The core of the Shaw Dome consists of calc-alkalic pillowed andesites and pyroclastic dacites (Pyke 1982). Isoclinal folds have locally been outlined parallel to the stratigraphy near the outer margins of the domes. These marginal folds could be common structural features; however, their delineation is very difficult because of the limited bedrock exposure.

The southern part of the Shaw Dome hosts five nickel deposits and several showings, which occur at the base of the komatiitic pile. The Redstone, Hart (Tontine), McWatters, Langmuir #1, and Langmuir #2 deposits occur in the Langmuir-Eldorado area at the southeast end of the dome (Fig. NI13). The ultramafic flows, which host the nickel sulphide deposits, appear to define a single stratigraphic horizon which overlies the felsic to intermediate metavolcanic sequence (Pyke 1970). Narrow bands of siliceous sulphide-bearing iron formation (sulphidic interflow metasedimentary units) are a common component of this lower felsic unit. The Texmont Mine, at the boundary of Bartlett and Geikie Townships, occurs within a similar stratigraphic setting. Here, mineralization occurs in a peridotite near the upper part of a felsic metavolcanic sequence. Intercalated bands of iron formation (sulphidic interflow metasedimentary units) also occur within the felsic metavolcanic sequence. The metavolcanic sequence which hosts the Texmont Mine is interpreted to be stratigraphically correlative with the metavolcanic sequence which hosts the deposits in the Langmuir-Eldorado area.

6.5.1. Redstone Nickel Deposit

The Redstone deposit is located 22 kilometres south-southeast of South Porcupine, in Eldorado Township. The property is reached by following the Langmuir Mine Road, then turning west onto the Springer Road (private lumber road) from a point three kilometres southeast of the Redstone River bridge. Follow the Springer Road for 10 kilometres, then turn west onto the Timmins Nickel road and continue for an additional 2.6 kilometres.

This property is owned 51 percent by Timmins Nickel and 49 percent by BHP-Utah Mines Limited. Probable minable reserves of 320,000 tonnes, at 2.91 percent Ni, were used to justify the mining decision in late 1988. Previous estimates were higher.

6.5.1.1. History

The following is a brief account of the property history:

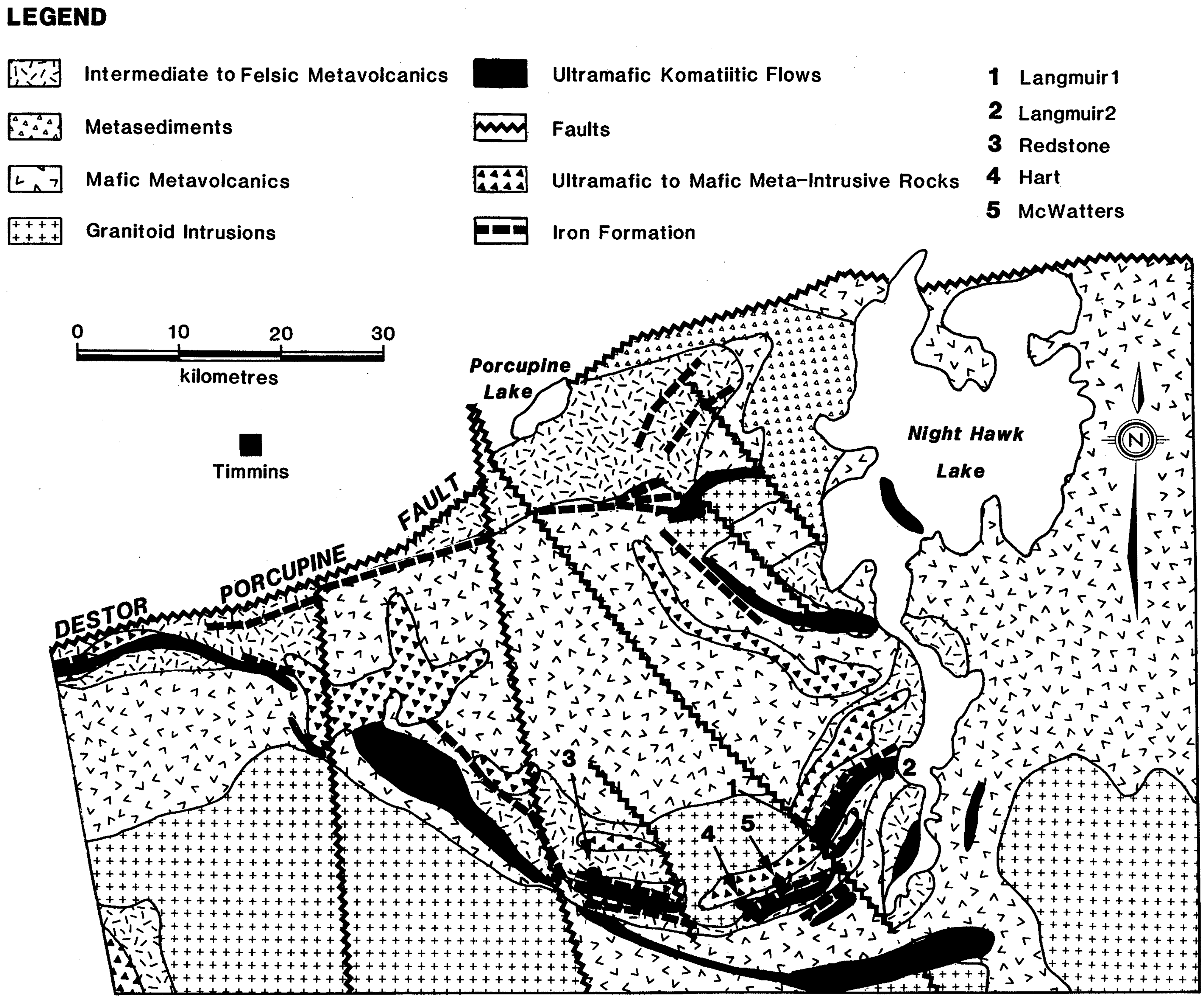


Figure NI13: Generalized geology of the southern Shaw Dome area, illustrating the location of the komatiite-associated, nickel-sulphide deposits (geology after Pyke 1982).

1976: Utah Mines Limited conducted Airborne Geophysical Survey;
1977: Three untested conductors were delineated and drilled in the spring of 1977. The first hole hit nickel sulphides beneath an iron formation. Reserves, calculated after 3170 metres of diamond drilling, were calculated at 220,500 tonnes, grading 2.00 percent Ni.
1978: Thirteen new electromagnetic conductors were drilled. Twelve conductors were attributed to barren iron formation and one was attributed to conductive overburden. A geophysical survey was carried out over extra claims.

Drilling by Utah Mines Limited consisted of 52 holes, and a total of 7500 metres. In 1989 Timmins Nickel purchased an interest in the property and drove a ramp at a 15 percent grade to the 96 metre level. Mining to date has been carried out on several shallow levels.

6.5.1.2. Geology

Felsic to intermediate metavolcanic rocks of the Deloro assemblage (Section 4.9; Deloro "group"; Pyke 1982) form the footwall of the nickel sulphide deposit. Sulphide facies iron formation (sulphidic interflow metasedimentary units) occurs at the top of the metavolcanic sequence. The mineralogically zoned Fe-Ni sulphides of both the R and S zones occur at or near the top of the felsic to intermediate metavolcanic sequence (Fig. NI14 and NI15). Komatiitic flows of the Bowman assemblage (Section 4.12.) form the hanging wall of the deposit and are subdivided into two units. The lowermost komatiitic rocks, immediately overlying the R zone, are massive, thick (25 metres), and very rich in MgO (> 40 weight percent). These unit 2 flows are located within a paleotopographic depression and are interdigitated with the felsic to intermediate metavolcanic rocks. They are overlain by a sequence of thin (10 metres), massive to spinifex-textured flows. Rock descriptions and the chemical composition of the various rocks related to the deposit are given by Robinson and Hutchinson (1982).

6.5.1.3. Mineralization

The mineralization consists of massive nickel sulphides grading up to 27 percent Ni over short intervals. The massive sulphide zone is overlain by a zone of disseminated sulphides containing 0.5 to 1.5 percent Ni. The massive sulphide zone in general has very sharp boundaries. The sulphides are pyrrhotite and pentlandite with minor millerite. The very high abundance of nickel in sulphide (> 20 weight percent), compared with that typical for komatiite-associated nickel sulphide (10 to 14 weight percent), is attributed to the replacement of the serpentinite assemblage by talc and carbonate and the concurrent destruction of iron-sulphides. The typical ore composition is approximately 2.29 percent Ni, 0.7 percent Cu, 0.03 percent Co, 0.1 g/tonne Au and 0.5 g/tonne PGE.

One of the most interesting aspects of the deposit is the intimate and variable relationship between nickel-sulphide mineralization and sulphide-bearing metasedimentary rocks, locally known as iron formations. In several places, including underground workings, a complete gradation from one into the other is observed. This has been documented underground at the west end of the nickel-sulphide mineralization. At the east end, a similar gradation has also been interpreted from drill core data. Below the limits of the deposit, as presently outlined, several exploratory holes have been drilled. Five of these holes have intersected nickel-sulphide mineralization and four have hit iron formation at the same stratigraphic horizon. A contoured long section of the base of the ultramafic pile suggests that there may be a paleotopographic control on the localization of the nickel sulphides, as was interpreted for the nearby Langmuir #2 mine by Green and Naldrett (1981).

There is also a broad stratigraphic variation within the deposit. The basal flow of the ultramafic package, at the base of which is found the most significant nickel-sulphide mineralization, varies in thickness from zero on the west side of the deposit, where an apophysis extends into the dacitic footwall, to a maximum thickness of 30 metres and then thins to the east as the ore is lost. Overlying ultramafic flows thicken with depth and to the east. There are also probably two more iron formation horizons in the overlying stratigraphy, one with an associated mineralized zone, the "S" zone.

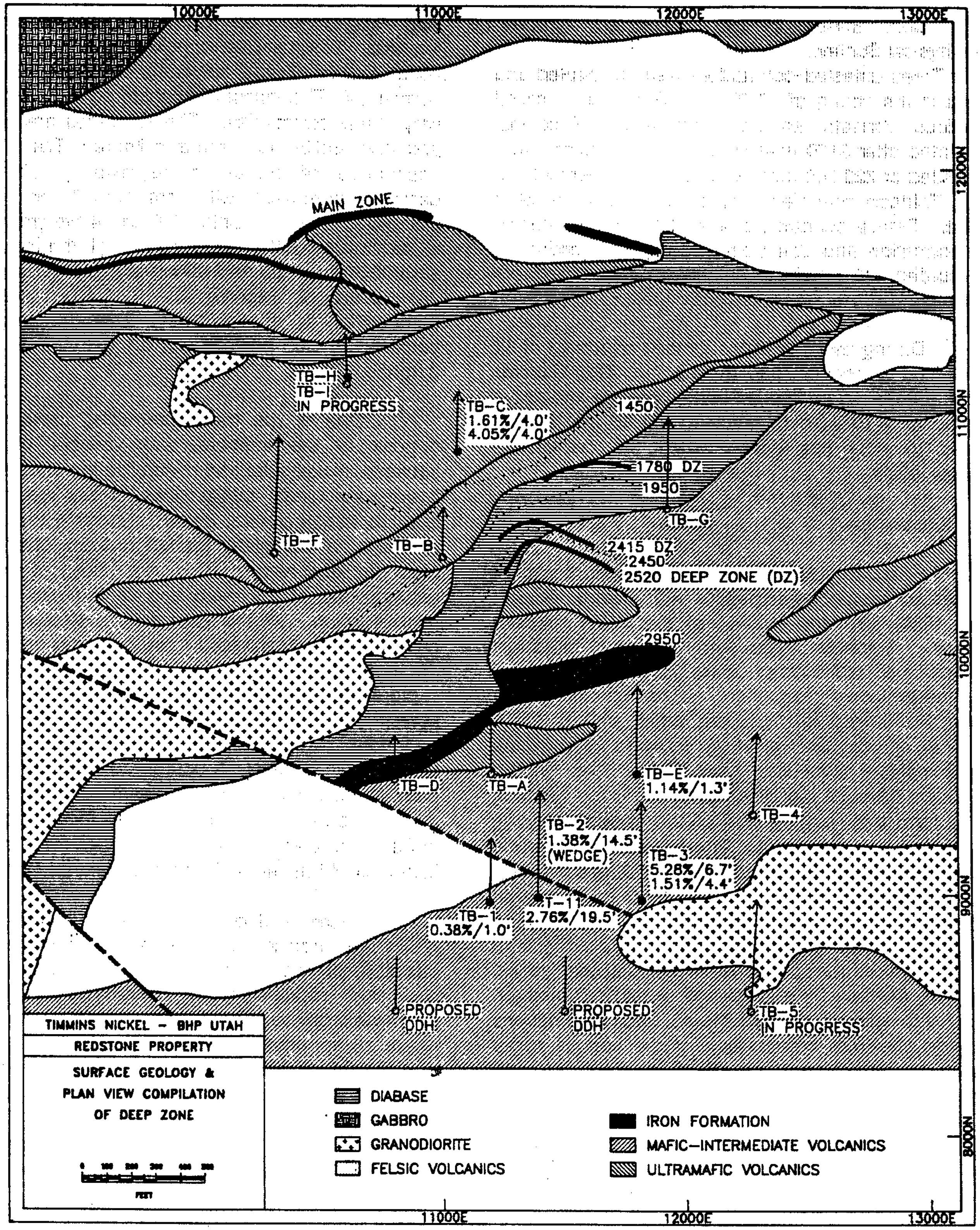


Figure NI14: Geological surface plan of the Restone property. Red lines represent the trace of the mineralized ore zones, projected to surface.

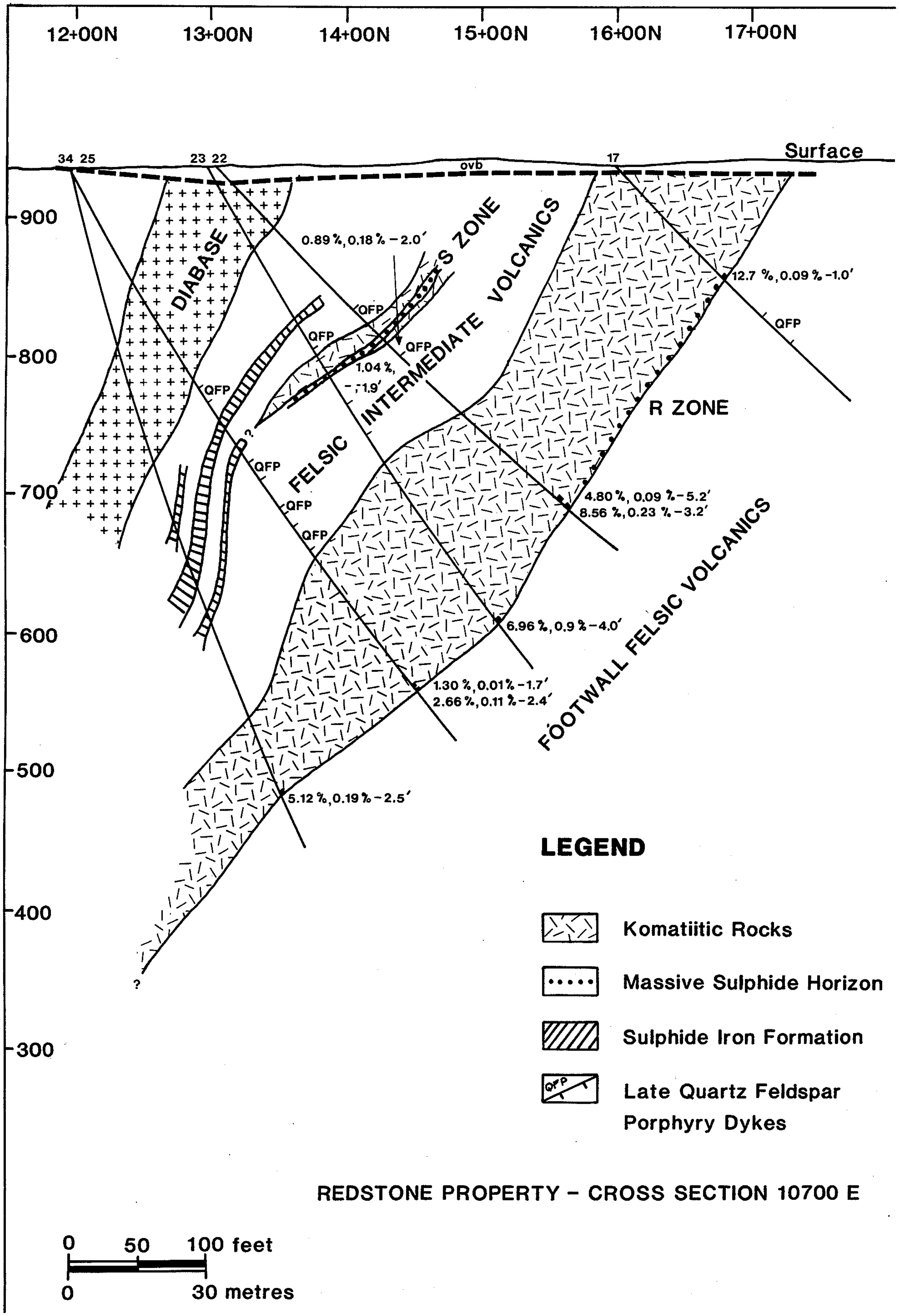


Figure NI15: Generalized geological cross-section through the Redstone nickel-sulphide deposit.

VOLCANIC-ASSOCIATED MASSIVE BASE METAL SULPHIDE MINERALIZATION

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The setting and characteristics of volcanic-associated, polymetallic, massive, base-metal sulphide mineralization are examined in three areas: 1) Kidd Creek Mine; 2) Kamiskotia meta-igneous complex; and 3) Potter Mine. Mineralization in these three areas occurs in three different geological settings. The purpose of this chapter is to provide basic information on the polymetallic, volcanic-associated base metal sulphide deposits in the Kidd Creek and Kamiskotia areas and on the meta-igneous rocks with which the deposits are closely associated. a discussion of the Potter Mine is presented in Section 6.3.3. Some specific tour stops are also given, but, as with other sections of this guide, access to all parts of the mining properties is dependent on the state of active mining.

Polymetallic base metal mineralization in the Kidd Creek Mine area occurs associated with a locally thickened (300 metres) sequence of high-silica rhyolitic flows and pyroclastic rocks, associated with tholeiitic and komatiitic metavolcanic rocks. In the immediate mine area, the geometry of the thickened felsic metavolcanic sequence, the prolate shape of the massive sulphide deposit, and the distribution of the associated alteration and stringer mineralization suggests that the localization of the Kidd Creek deposit and associated felsic metavolcanic rock, may have been controlled by a synvolcanic rift system.

The massive sulphide deposits in the Kamiskotia area also occur within a mixed sequence of mafic and high-silica rhyolitic metavolcanic rocks, associated with a layered tholeiitic intrusion. The sulphide deposits are hosted within both felsic and mafic sequences. The volcanological characteristics of this area are consistent with some of those typical of modern cauldera structures.

Polymetallic base metal mineralization in the Potter Mine area occurs within a sequence of tholeiitic and komatiitic metavolcanic rocks, associated with a layered, tholeiitic intrusion. Felsic metavolcanic rock, if present, constitutes a very minor proportion of the metavolcanic sequence. The mineralization in this komatiite-tholeiite sequence appears to be related to a possible synvolcanic fault (or rift).

Kamiskotia Area

P. Binney[1] and T. Barrie[2]

Metavolcanic rocks in the Kamiskotia meta-igneous complex are host to four past producing mines (Fig. KAM1). Three of the mines (Genex, Kam-Kotia, Canadian Jamieson) were originally discovered as surface outcrops of mineralization. The Jameland mineralization was discovered by diamond drilling of a geophysical conductor, associated with barren massive sulphides, during exploration by Dominion Gulf in the late 1950's and early 1960's. Subsequent drilling intersected the base metal-bearing massive sulphide mineralization.

The Kam-Kotia Mine, located in Robb Township, produced approximately 6.0 million tonnes of ore containing 1.09 percent Cu, 1.03 percent Zn and 3.5 g Ag/t (Luhta et al. 1990), from three ore zones. The Jameland Mine, located 2 km southeast of the Kam-Kotia, in Jamieson Township, produced 461,800 tonnes of ore with 0.99 percent Cu, 0.88 percent Zn and 3.5 g Ag/t (Luhta et al. 1990), from six separate copper-rich sulphide lenses and one zinc-rich sulphide lens. The Canadian Jamieson Mine produced 826,400 tonnes of ore containing 3.5 percent Zn and 2.3 percent Cu from three separate sulphide ore lenses at the north end of Godfrey Township. The smallest producer is the Genex Mine. This deposit, which comprises one stratabound sulphide lens and numerous stockwork zones, produced 242 tonnes of concentrate containing 21 to 27 percent Cu, during its relatively short life (1966 to 1967). The Kam-Kotia Mine produced a small tonnage of copper-rich ore during the second World War. All of the other metal production from the Kamiskotia area occurred between 1960, when the Kam-Kotia open pit was placed in production, and 1972, when the Kam-Kotia and Jameland Mines closed.

Although these Cu-Zn deposits are the only ones with recorded production, deposits of stockwork sulphide mineralization or massive, but barren, stratabound sulphide lenses are known throughout the Kamiskotia metavolcanic complex (Fig. KAM1). Some of the more significant showings are:

1) Steep Lake, which is a large alteration and stockwork sulphide system north of the Genex Mine in Godfrey Township;

2) the Teck showing, consisting of a semi-massive zone of pyrrhotite and minor sphalerite which occurs at a slightly higher stratigraphic level than Genex, in southern Godfrey Township; and
3) the Dominion Gulf deposit, a low grade, massive sulphide deposit which lies along strike and to the west of the Jameland Mine.

7.1.1. Regional Geological Setting

The Kamiskotia meta-igneous assemblage includes volcanic rocks of the Kamiskotia metavolcanic complex and plutonic rocks of the Kamiskotia gabbroic (intrusive) complex (Section 4.9.; Fig. KAM1). Metamorphic grade ranges from the sub-greenschist to middle amphibolite facies, with higher metamorphic grades generally proximal to the margins of large felsic granitoid intrusions.

The Kamiskotia gabbroic (intrusive) complex, in the western part of the Kamiskotia area, is a large, deformed tholeiitic intrusive complex (Fig. KAM1). It is overlain by, and is in part gradational with, volcanic rocks of the Kamiskotia metavolcanic complex; including basalts, rhyolites, and volumetrically minor, evolved basalts and andesites. The Kamiskotia metavolcanic complex hosts four volcanogenic massive sulfide deposits. In a general sense, the stratigraphic succession has a near-vertical dip and faces to the east and northeast. Several granitoid masses have intruded the stratigraphy to the west and south, including a tonalite intrusion in western Turnbull

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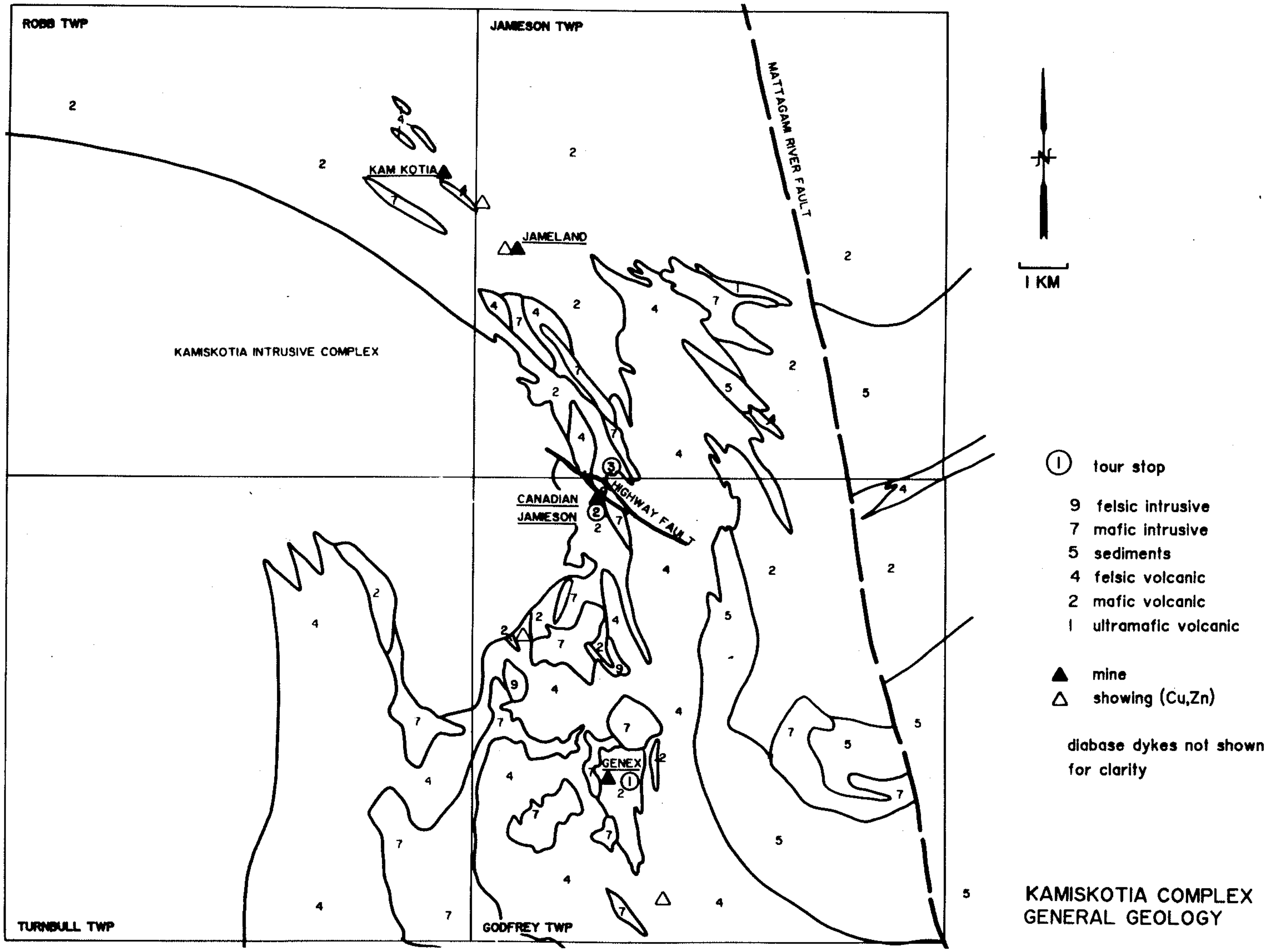

Figure KAM1: Simplified geology of the Kamiskotia area, showing the location of tour stops.

Township which exhibits mixed magma textures with fine-grained and locally pillowed Kamiskotia gabbroic complex rocks. This intrusion is believed to have intruded the base or the margin of the Kamiskotia gabbroic complex during its crystallization. Volcanic rocks of the Kamiskotia meta-igneous complex are bounded to the west by the Kamiskotia gabbroic complex and to the east by the north-trending Mattagami River fault. The boundaries to the north and south are less-well constrained due to poor exposure. In general terms, the Kamiskotia metavolcanic complex is bounded to the north by older rocks of the Kidd - Munro assemblage (Section 4.3.), and to the south by metavolcanic rocks of the Carscallen assemblage (Section 4.10.). Early Proterozoic Matachewan diabase dikes trend north-northwest and cut rocks of the Kamiskotia metavolcanic complex.

7.1.2. Detailed Geology

7.1.2.1. Kamiskotia Metavolcanic Complex

Principal rock types in the Kamiskotia metavolcanic complex include: massive, pillowed and fragmental (pillow breccia) mafic metavolcanic rocks; massive, flow banded, fragmental and tuffaceous felsic metavolcanic rocks; massive mafic intrusions; and massive to autobrecciated and flow banded felsic intrusions. A bimodal and also bilateral distribution of lithologies is developed. Mafic extrusive and intrusive (sills) rocks predominate in the northern part of the complex, with some intercalated felsic flows and tuffs proximal to the Kam-Kotia and Jameland Mines (Fig. KAM1). Mineralization at Genex, Steep Lake and Canadian Jamieson is hosted by mafic metavolcanic rocks. To the south of the Genex Mine, felsic flows, fragmental rocks and tuffs predominate, and comprise greater than 75 percent of the complex.

Textural evidence exists for both subaqueous and subaerial deposition of metavolcanic rocks. The presence of pillowed mafic flows near all deposits indicates the subaqueous nature of the mineralizing process. Along strike from the known areas of mineralization, the presence of welded tuffs, block and ash flows with welded lapilli, and fine-ash base surge deposits indicate that significant parts of the volcanic pile were deposited subaerially. This close spatial and temporal relationship between subaerial and subaqueous rocks is consistent with a tectonic environment in which significant vertical movement with respect to sea level occurred in short time intervals. This may indicate a generally shallowing upward of the volcanic pile, with subaerial deposition at the top of the sequence, or resurgent volcanism and cauldron collapse (e.g., Thurston 1986; Morton and Franklin 1987).

7.1.2.2. Geochemistry

Mafic rocks are divided into four divisions on the basis of P_2O_5, TiO_2, SiO_2 and Al_2O_3 contents: tholeiites, iron tholeiites, icelandites and high alumina basalts. Here the term icelandite refers to a rock of intermediate composition and greater than 0.3 percent P_2O_5. Two types of icelandites are recognized, one with low TiO_2 (<2.0 percent) and the other a high TiO_2 variety. An example of the discrimination between icelandites and other basalt types is illustrated on figure KAM2. These divisions do not relate directly to the rock types as defined by AFM or Al_2O_3 - FeO^*- MgO diagrams, but are helpful empirically for dividing evolved tholeiitic suites, such as the Kamiskotia metavolcanic complex, into discrete chemo-stratigraphic units.

Felsic metavolcanic rocks of the Kamiskotia meta-igneous complex are rhyolite and high-silica rhyolite, having relatively flat REE patterns ($[La/Yb]_n$ = 1-4), pronounced negative Eu anomalies (Eu/Eu^* = 0.20-0.61), elevated Zr and Y abundances, low Zr/Y (2-6), and low abundances of Sc and Sr (Lesher et al. 1986; Barrie 1990).

7.1.2.3. Structure

Metavolcanic and mafic intrusive rocks within the Kamiskotia meta-igneous complex form a broad monoclinal arc that faces to the east and northeast. Stratigraphic tops are consistently to the east or northeast as established by pillow tops, and loading, slump structures and grading in reworked, felsic tuff. In southern Godfrey Township the rocks are overturned and dip 65° to the west. In the vicinity of Genex Mine, rocks are overturned and dip 80° to the west. Dips are near vertical further to the north.

Penetrative deformation is uncommon in the rocks of the Kamiskotia meta-igneous complex, and is generally confined to well-defined, ductile shear zones, particularly within altered metavolcanic rocks proximal to mineralization. At the Canadian Jamieson Mine, penetrative deformation (and alteration) has destroyed

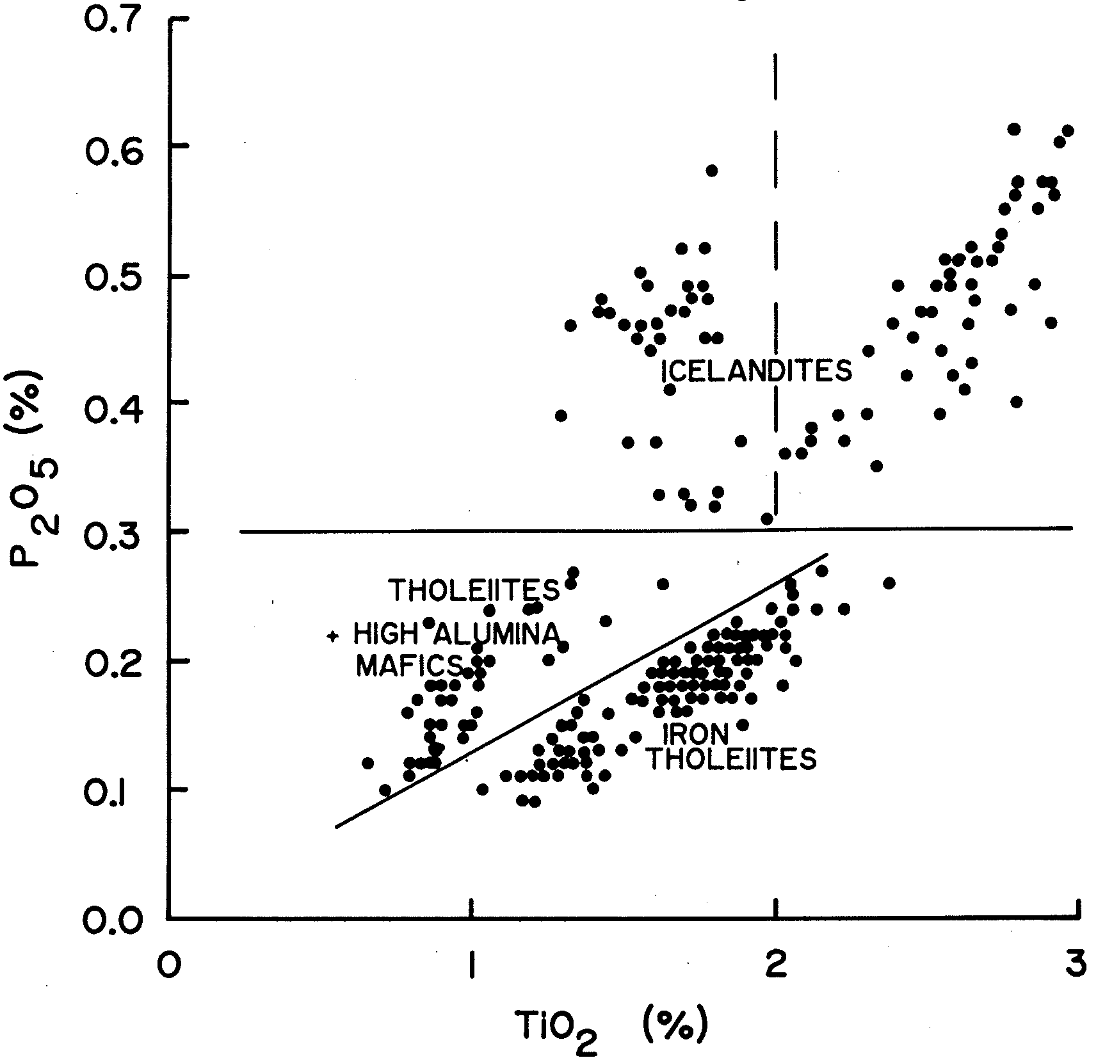

Figure KAM2: Typical discrimination diagram used to distinguish icelandites from various other basalt types.

original rock structures in parts of the stratigraphy between the Central and North ore zones. Faults are concentrated immediately north of the mine, where a horizontal, dextral displacement of 1.5 km occurs on one major fault system. Numerous, smaller faults with horizontal, dextral displacements of 50 to 100 metres, are present on the southern part of the property. At the Genex Mine and at Steep Lake, a prominent, east-trending foliation is present. Here, brittle deformation is noted principally as east-trending normal faults with displacements from tens to hundreds of metres.

7.1.3. Rock Alteration

Two types of alteration are prominent in the vicinity of the deposits: 1) silica-sericite-chlorite alteration; and 2) carbonate. Silica-sericite-chlorite alteration is more common and more widespread. It is accompanied by a loss of Na_2O and CaO. At the Genex deposit and at Steep Lake, values of Na_2O + CaO are commonly less than 0.10 percent (Fig. KAM3). The alteration in both areas forms broad, crudely conformable zones that crosscut stratigraphy on a scale of 100's of metres.

A large alteration zone is not associated with the Kam-Kotia deposit. Footwall rocks beneath part of this deposit have undergone strong alkali depletion, whereas other footwall rocks to the ore zone are unaltered.

At the Canadian Jamieson deposit, pronounced alteration defined by replacement by ferroan carbonate of undetermined mineralogy, is confined to mafic fragmental rocks that also host two of the ore zones. This replacement carbonate is rusty weathering on the outcrops and drill core that has been exposed on surface for some time.

7.1.4. Temporal Constraints

In-situ, flow-banded rhyolite from southern Godfrey Township, and a pegmatitic quartz gabbro from the Kamiskotia gabbroic complex have essentially coeval ages of 2705 +/- 2 Ma and 2707 +/- 2 Ma respectively (Barrie and Davis 1990). Chemically similar rocks near the Kidd Creek Mine 25 km to the northeast, have ages of 2717 +/-2, 2716 +/-4 Ma (Prosser Township), and 2705 +5/-3 Ma (Reid Township). The Reid Township rhyolite is chemically and temporally similar with the Kamiskotia rhyolite, and it may represent a distal, rhyolite-ash deposit that originated from a source in the Kamiskotia area. Voluminous granitoid magmatism to the west and south of the Kamiskotia meta-igneous complex occurred at 2696 +/-1.5 to 2694 +/-4 Ma (Barrie and Davis 1990).

The tour of the Kamiskotia complex will include three stops, two at past producing deposits, and one to demonstrate the close spatial relationship between subaqueous, mineralized rocks and subaerial felsic pyroclastic deposits. The two mine stops are located on private land. You are a guest here and in consideration of the amount of work done stripping, mapping and preparing these outcrops, you are asked to take only photographs and leave only footprints. NO HAMMERS will be allowed on the tour outcrops.

7.1.5. Genex Deposit

An example of intense hydrothermal activity, with accompanying quartz-sericite-chlorite alteration, is illustrated at the Genex Mine. In proximity to the hydrothermal vent area, this alteration has destroyed many of the original rock textures.

The initial claims in the Genex-Aconda Lake area were staked in 1926 based on outcrops of base metal mineralization. The property was explored periodically by surface trenching, geophysical survies and diamond drilling until 1964, when Genex Mines Limited purchased the claims. They commenced an intensive program of geophysics, diamond drilling and underground development. A small shaft was sunk to 84 metres with levels at 38 metres and 76 metres. Production commenced in 1966, but was terminated in 1967, following bankruptcy. Since 1967 the property has been explored by United Obalski Mining Company Limited, Kennco Explorations Canada Limited and latterly Kidd Creek Mines Limited and Falconbridge Limited. Much of the current map information is derived from an M.Sc. thesis (Legault 1985) sponsored by Kidd Creek Mines Limited

7.1.5.1. Property Geology

The Genex deposit comprises one stratabound massive sulphide lens, and several mineralized stockwork zones containing chalcopyrite and sphalerite. The mineralization is hosted by a north-trending, west-dipping, overturned sequence of massive, pillowed, and fragmental mafic metavolcanic flows, which have been intruded by synvolcanic flow-banded and autobrecciated felsic metavolcanic rocks (Fig. KAM3). The stratigraphy is also intruded by several thick mafic sills and late, north-trending, diabase dikes. Major diabase dikes are spaced approximately 300 metres apart. The dikes dilate the stratigraphy but appear to have no other effect.

The stratigraphic relationships within the Genex deposit area are best examined in relationship to the whole rock geochemistry and corresponding rock classification (Fig. KAM4). It is not possible to present a simple stratigraphic column through the deposit area, because synvolcanic growth faults had a strong control on the emplacement of the mafic intrusive and metavolcanic rocks. To the west, felsic flows and fragmental rocks stratigraphically underlie the mineralized area. These high-silica rhyolite units occur as hectare size blocks within a mafic intrusion and as a discrete unit in contact with the basal mafic rocks of the Genex stratigraphy. These felsic units are informally referred to as tholeiitic felsic metavolcanic rocks (e.g., Fig. KAM4). Chemical discrimination indicates at least two separate mafic intrusions underlie the Genex area (Fig. KAM3 and KAM4). The older intrusion resembles an iron-rich tholeiitic basalt.

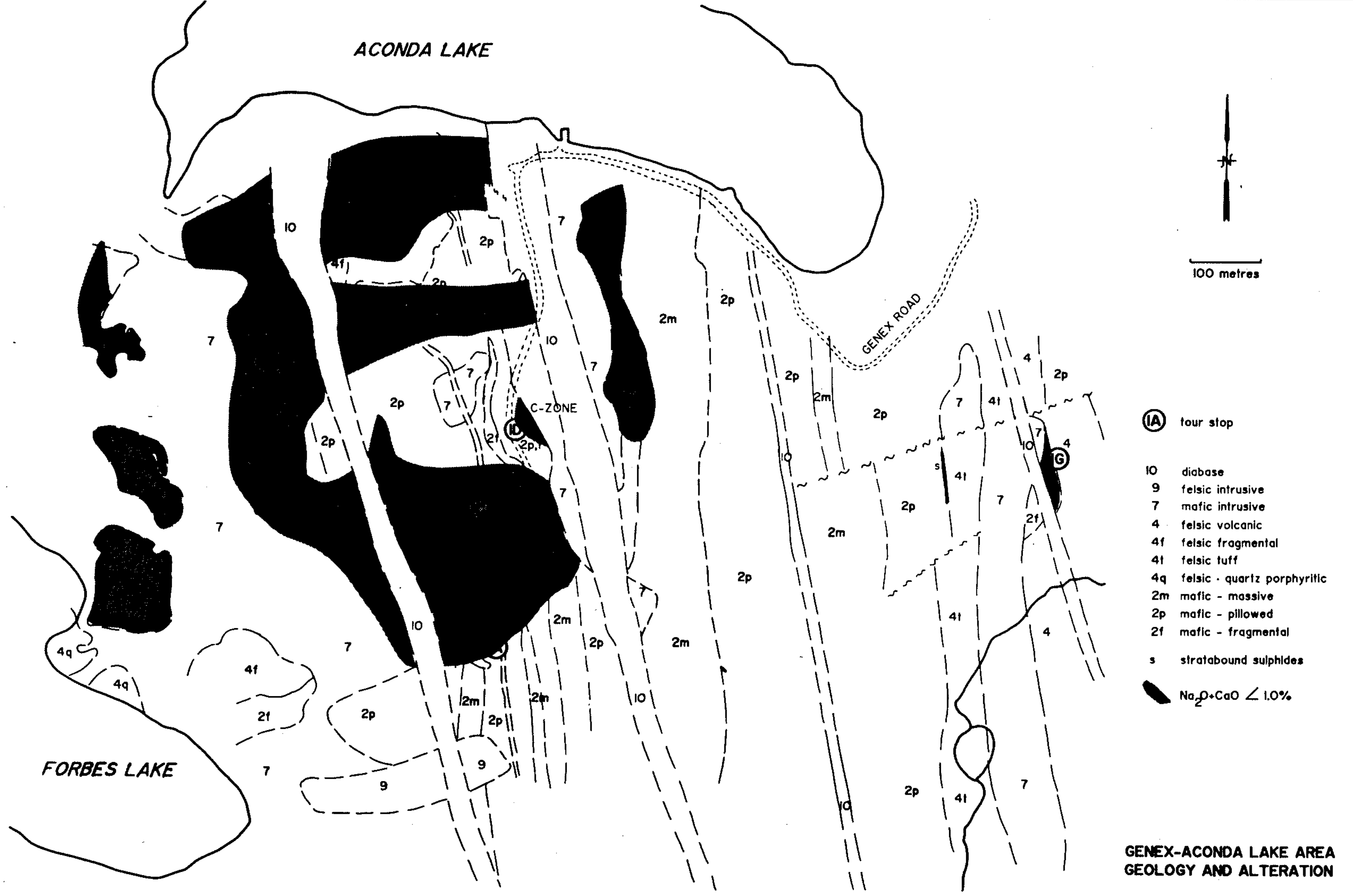

Figure KAM3: Simplified geology of the Genex-Aconda Lake area, illustrating the distribution of an extensive zone of sodium and calcium depletion.

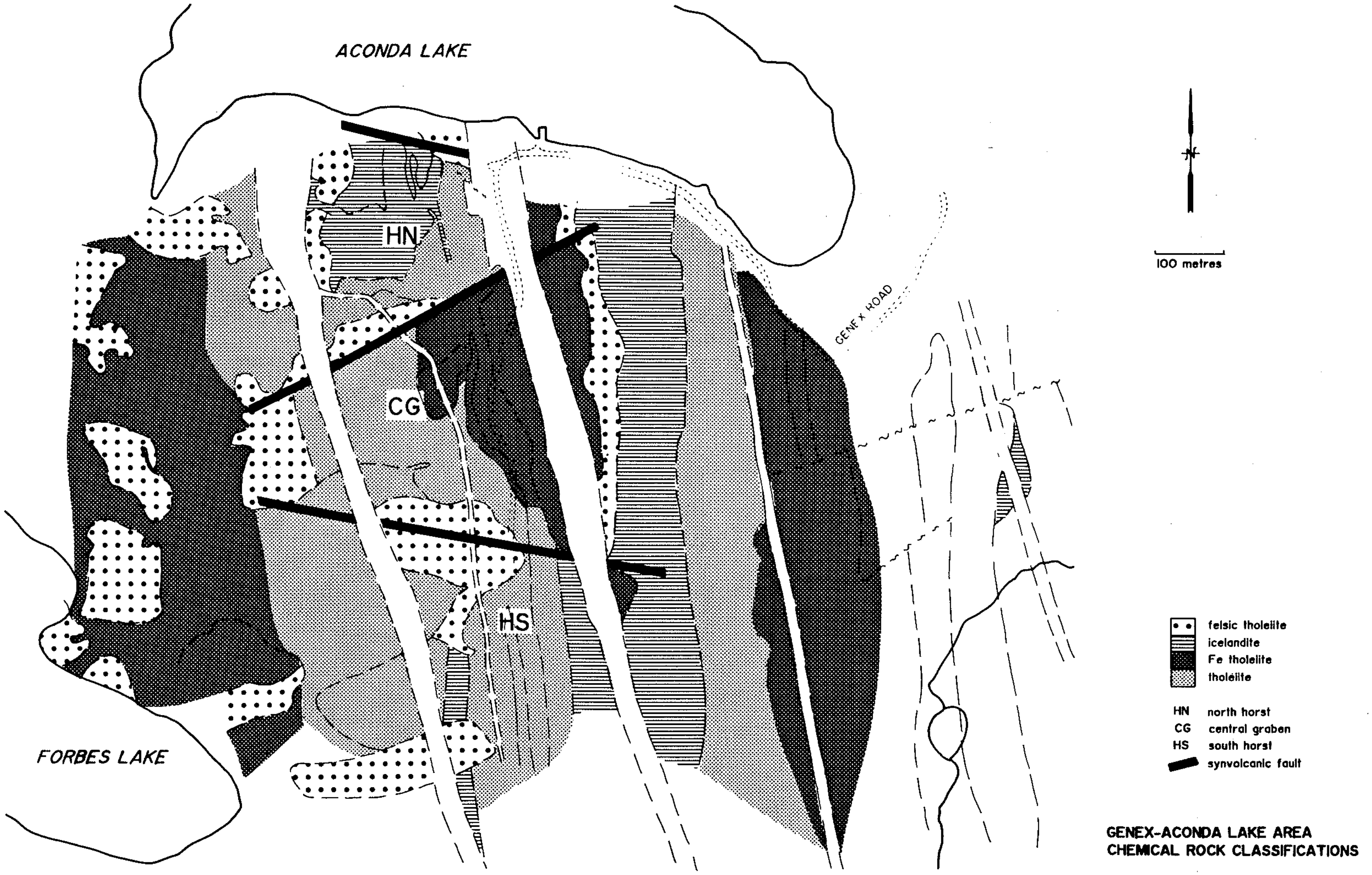

Figure KAM4: Chemical rock classification of the Genex-Aconda Lake area.

The younger intrusion is altered and resembles a tholeiitic basalt, with chemistry similar to the immediately overlying pillowed basalt flows. The mafic rocks above the basal felsic unit are laterally constrained by synvolcanic faults. In the central graben area (CG on Fig. KAM4), tholeiitic, pillowed basalts are overlain by high-iron, tholeiitic, pillowed and fragmental metavolcanic rocks and a mafic intrusion. On the horst to the north (HN on Fig. KAM4), icelandite intrusions and spatially related pillowed flows overlie the basal felsic metavolcanic rocks and are, in turn, overlain by tholeiitic basalts. The lateral transition from tholeiitic to iron-rich tholeiitic basalt from north to south across the fault is consistent with the syn-volcanic timing of the fault. In the southern horst (HS on Fig. KAM4), thin units of massive and pillowed icelandite flows are interbedded with a thick section of massive and pillowed, tholeiitic basalts. Coincident with the proposed position of the synvolcanic faults are synvolcanic intrusions of autobrecciated and flow banded tholeiitic rhyolite (Fig. KAM4). The shallow, synvolcanic nature of this intrusion is suggested by the absence of clasts of felsic detritus in the adjacent graben structure even though talus slopes of mafic debris occur on the graben margin. Hydrothermal alteration occurs within the felsic intrusion as well as the adjacent mafic metavolcanic rocks. The contacts of the felsic intrusions with the adjacent mafic flows are altered, but distinct.

Overlying the mafic metavolcanic sequence is a laterally extensive, massive to fragmental, tholeiitic felsic unit. This felsic flow ends near the southern synvolcanic fault, but continues to the north, beneath Aconda Lake. Above the felsic flow, the presence of thick, laterally continuous, massive and pillowed mafic flows marks the end of the development of the topography generated by synvolcanic fault (Fig. KAM4). A massive icelandite flow is succeeded by pillowed tholeiitic basalt flows and intercalated, massive and pillowed, high-iron, tholeiitic basalt. Further to the east, the mafic stratigraphy is succeeded by felsic tuffs, correlative with the felsic metavolcanic rocks in southern Godfrey Township. The felsic tuffs overlying the Genex stratigraphy are intruded by a mafic sill. Diamond drilling has demonstrated the presence of thin, pillowed and massive, mafic flows which are intercalated with the felsic tuffs to the east (Fig. KAM3).

7.1.5.2. Property Alteration

In outcrop, the most prominent alteration at Genex is silicification. East-trending zones of silicification, displaying a box-work texture, crosscut the primary fabric of the metavolcanic rocks. Most mafic intrusions were later than, and therefore were not affected by, the silicification. Primary structures in the pillowed basalt flows, such as concentric cooling cracks and interpillow hyaloclastite, are enhanced by silicification. Higher temperature replacement chlorite, flanking the felsic intrusions, occurs principally as veins up to ten centimetres in width. These veins, which contain chlorite and sulphides, crosscut the silicified mafic metavolcanic rocks and locally coalesce to form a mass of chlorite and sulphides, in which fragments of silicified pillow fragments remain. Alteration in the felsic intrusions includes silicification and weak to moderate sericitization.

A broad, stratabound blanket of alteration occurs in the basal felsic rocks and locally in parts of the mafic intrusion (Fig. KAM3). Three alteration apophyses trend east from the stratabound alteration and crosscut the stratigraphy. These apophyses are localized along the inferred synvolcanic faults and are coincident with the subvolcanic felsic intrusions. No alteration occurs in the central part of the graben structure, except immediately underlying the C-zone stratabound sulphide mineralization. To the east, alteration is coincident with a felsic fragmental unit and the overlying, mineralized exhalite.

7.1.5.3. Genex Mineralization

The principal mineralization consists of fracture-filling and disseminated pyrite, sphalerite, and chalcopyrite, which occur within stockwork zones. Cross-cutting alteration is coincident with the mineralized stockwork zones. A single, massive sulphide lens, known as the C-zone, is conformable with the stratigraphy and is underlain by a small stockwork zone. The massive sulphides contain one to two percent Cu as chalcopyrite. The location of the alteration pipe, stockwork mineralization, and felsic intrusions is strongly controlled by the position of the inferred synvolcanic faults, on the graben margins.

A broad zone of stockwork mineralization exists in the tholeiitic, pillowed basalts. On surface, this zone of alteration and mineralization terminates within the tholeiitic basalts. Based on diamond drilling, the zone of alteration and mineralization terminates abruptly against the base of the high-iron, tholeiitic basalt in the central graben. A small zone of alteration within the high-iron, tholeiitic basalts is associated with the stratabound C-zone mineralization. Alteration of the syn-volcanic intrusions indicates that the hydrothermal system operated synchronously with volcanism.

7.1.5.4. Stop 1A

The tour of the Genex stratigraphy and mineralization (Fig. KAM3) begins to the south of the old mine area with an examination of north-trending pillowed basalts, which are cut by a strong, east-striking foliation with coincident silicification and chloritization.

7.1.5.5. Stop 1B and 1C

At Stop 1B, the felsic, subvolcanic intrusion is exposed in outcrops of autobrecciated, flow-banded and sericitic, aphyric rhyolite. The northern contact of the intrusion with bounding mafic units is partially obscured by strong silicification at Stop 1C. Chloritization and minor sulphide mineralization are also observed at this stop.

7.1.5.6. Stop 1D

In the centre of the graben, a large outcrop provides exceptional exposures of pillowed basalt with prominent budding, lava tubes and hyaloclastite-rich flow margins. The pillowed flows are cut by stockwork sulphides underlying the C-zone stratabound sulphide mineralization which is also exposed at this location. A large, unaltered sill, similar in composition to the adjacent metavolcanic rocks, truncates the stratigraphy to the east on this outcrop.

7.1.5.7. Stop 1E

At this stop, a traverse from west to east will be made through the northern horst. Exposed are the altered felsic fragmental rocks that underlie the mafic Genex stratigraphy, the massive and pillowed facies of the icelandite flows, and the overlying, tholeiitic, pillowed mafic flows.

7.1.5.8. Stop 1F

The unaltered central diabase and mafic sill are crossed to access Stop 1F, which includes outcrops of the altered upper-rhyolite unit and overlying siliceous exhalites, with associated base metal mineralization.

7.1.5.9. Stop 1G

The final stop in the Genex area is approximately 600 metres further to the east from Stop 1F. A thick section of relatively unaltered, massive and pillowed basalts are traversed, in addition to an unexposed contact with overlying felsic tuffs. This contact, only observed in drill core, marks the position of a stratigraphic time break where semi-massive pyrrhotite and minor chalcopyrite were deposited along a strike length of 400 metres. At Stop 1G, located east of the mafic-felsic contact, massive and tuffaceous felsic units and a small vent breccia are exposed. The large blocks and chaotic mixture of mafic material and the presence of altered felsic metavolcanic rock, indicate proximity to a volcanic vent. A short hike to the north from this last stop leads to the Genex access road.

7.1.6. Canadian Jamieson Mine

Two features are emphasized at the Canadian Jamieson Mine: 1) the lack of a large alteration "root" beneath the deposit; and 2) the role of mafic fragmental metavolcanic units in channelling ore fluids.

In 1926 a portion of the Canadian Jamieson Mine property was staked and explored unsuccessfully for gold. George Jamieson restaked the property in 1941 and located the copper-zinc mineralization of the south ore zone. In 1943, Jamieson personally financed the drilling of 12 AX holes, totalling 762 metres, but no economic mineralization was located. Canadian Jamieson Mines Limited, incorporated in 1964, conducted a diamond drill program totalling 11,669 metres and discovered sufficient ore to place the property into production. The deposit was mined from four levels and serviced from a shaft 230 metres deep . A fifth level was completed solely for exploration. Mining commenced in 1966 and ceased on February 12, 1971. Total production was 826,400 tonnes grading 2.3 percent Cu, 3.5 percent Zn and 24.2 g Ag/t.

7.1.6.1. Alteration

Alteration in the basalt flows above the south ore zone includes silicification, bleaching, and Na_2O+CaO depletion. Sericitization and silicification are confined to felsic flows and fragmental rocks overlying the central ore zone. The principal alteration was sericite, and locally chlorite, in the immediate footwall of the ore zones. Apparently the role of carbonatization in the hydrothermal process was not recognized.

7.1.6.2. Mineralization

The Canadian Jamieson deposit comprises three stratabound massive sulphide lenses; the south, central and north ore zones (Fig. KAM5). Mineralization is hosted by a north- to northwest-trending, northeast-facing sequence of mafic metavolcanic rocks and minor, intercalated felsic flows. All of the mafic and felsic metavolcanic rocks in the vicinity of the ore zones show chemical affinity to iron-rich tholeiitic basalt. In the mine area, the stratigraphic assemblage is intruded by a thick icelandite sill which caps the known mineralization. The sill extends for 800 metres to the south. Felsic intrusions to the east are in fault contact with the sill and are unrelated to the mine stratigraphy. As at Genex, numerous diabase dikes cut and dilate the stratigraphy and ore zones, but have little other effect.

The stratigraphic relationships in the vicinity of the Canadian Jamieson deposit and the varying dips of the ore zones are perhaps best explained by reference to thin, felsic, tuff beds that are intercalated with the basalts. To the south of the mine, a major constructional ridge is formed by massive and pillowed basalt flows. This ridge is flanked to the north by a basinal depression, which was filled with mafic fragmental rocks (talus aprons or debris flow deposits), pillowed basalts, and thin beds of waterlain felsic tuff. The angular relationship between the mafic fragmental rocks, which have a strike of 305°, and the felsic tuff beds, which have a strike of 360°, suggests that the paleoslope, which existed on the margin of the mafic ridge, had up to a 55° dip. The felsic tuff is overlain by, and intercalated with, pillowed basalts.

Immediately below the south ore zone, a felsic tuff bed is overlain by sulphidic, iron-carbonatized, mafic fragmental rocks. The south ore zone is apparently hosted by the mafic fragmental rocks. Overlying the south ore zone are altered, pillowed flows which are depleted in sodium and calcium. From published mine plans, the central ore zone was at the top of this altered, pillowed basalt unit, in contact with an overlying felsic flow and fragmental unit. The ore zone may have been hosted by mafic fragmental rocks, but mine plans do not provide sufficient detail to determine this. Overlying the sheared, silicified, and sericitized felsic unit is another thick section of sulphidic, carbonatized, mafic fragmental rocks. This upper, mafic fragmental unit is the host for the north ore zone. A thick icelandite sill overlies the north ore zone and marks the upper boundary of economic mineralization.

Massive ore at the Canadian Jamieson Mine consisted of 75 percent sulphide and included pyrite, sphalerite, chalcopyrite and pyrrhotite. The hanging wall of the orebody was usually barren, but footwall rocks were pyritic and locally contained sufficient chalcopyrite to be mined.

The mineral deposits at Canadian Jamieson are not characterized by the extensive, fault-controlled, alteration pipes which are so readily apparent at Genex. The hydrothermal fluids were apparently channelled by the mafic fragmental rocks which are strongly carbonatized and sulphidized adjacent to the mineral deposits.

7.1.6.3. Stop 2A

The tour of the Canadian Jamieson property (Fig. KAM5) commences in pillowed basalts which underlie the mine stratigraphy, and proceeds up the stratigraphic section, to the east.

7.1.6.4. Stop 2B

Proceeding east from Stop 2A, a large, north-trending diabase dike is crossed to arrive on the outcrops of the first major, felsic tuff horizon. This tuff, weakly silicified and cut by foliation, still contains recognizable bedding which provides a reasonable estimate of the paleohorizon.

7.1.6.5. Stop 2C

Following the of tuff to the south, the angular

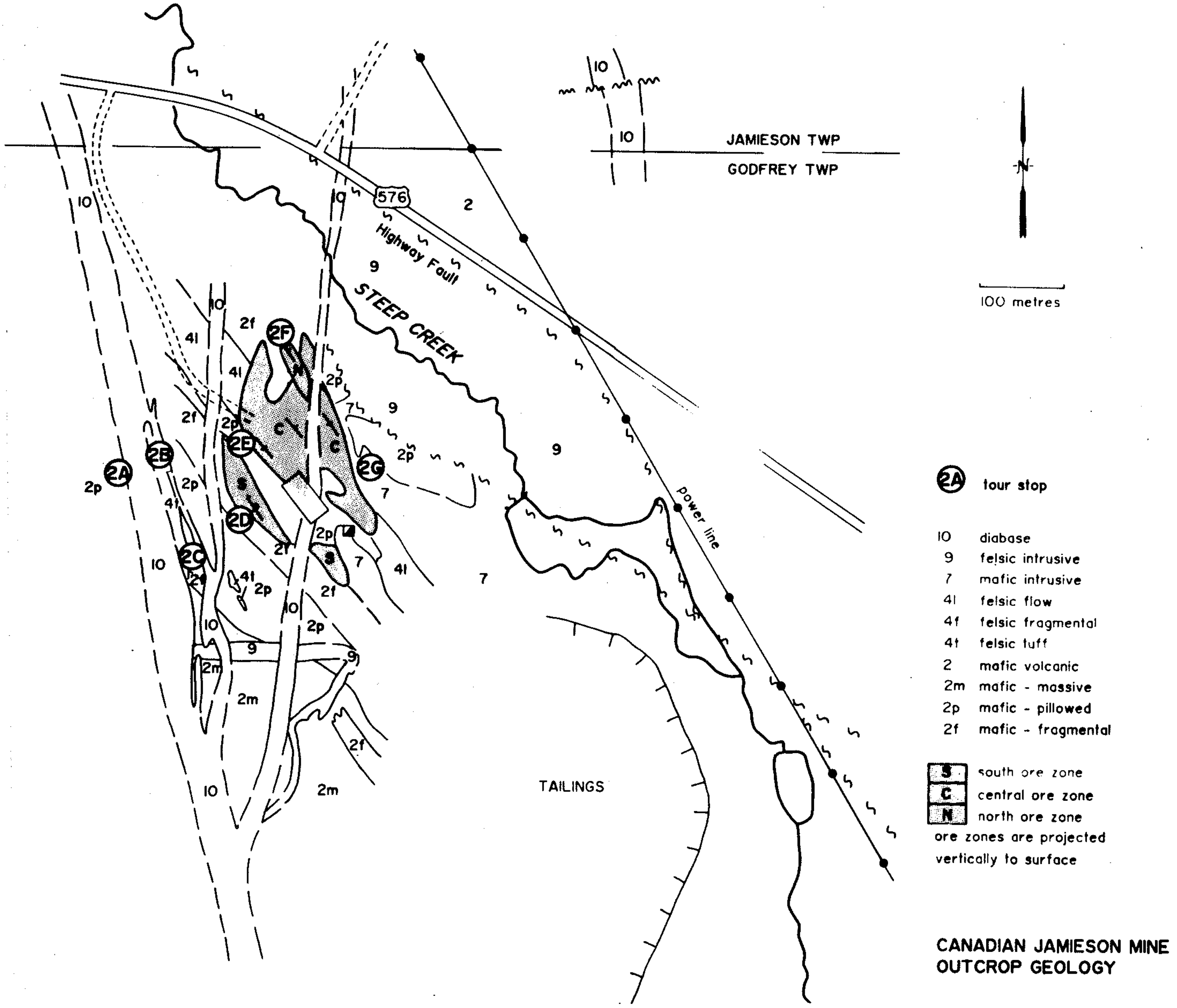

Figure KAM5: Detailed geology of the Canadian Jamieson property, illustrating the location of the north, central, and south ore zones and the tour stops.

relationship between the tuff and mafic fragmental rocks (talus) is noted. This angular relationship provides an indication of topographic relief on the flank of the mafic ridge.

7.1.6.6. Stop 2D

From Stop 2C to the south ore zone area, a series of massive and pillowed mafic flows, interlayered with thin felsic tuff horizons, are traversed. In the outcrops of the immediate footwall rocks to the south ore zone, another mafic fragmental horizon is exposed that has a carbonatized matrix and contains sulphide clasts.

7.1.6.7. Stop 2E

Overlying the south ore zone are bleached pillowed basalts and sericitized and silicified felsic flow lobes and fragmental rocks. A strong penetrative foliation obscures primary textures in the felsic units. The Central Ore Zone occurs in the subsurface, at the contact between the basaltic and overlying felsic metavolcanic rocks. This contact is buried beneath the mill building and the paved parking lot.

7.1.6.8. Stop 2F

The surface trace of the north ore zone is exposed in a large outcrop of carbonatized and sulphidic mafic fragmental rock, immediately overlying the felsic metavolcanic units.

7.1.6.9. Stop 2G

Overlying the north ore zone is a massive, icelandite sill which marks the end of the ore forming process at the Canadian Jamieson Mine. From this outcrop, a short walk to the northeast leads back to the main road (Highway 576).

7.1.7. Jamieson Township

The final stop is located in Jamieson Township, just north of the Canadian Jamieson Mine. The outcrops to be visited, although physically adjacent to the Canadian Jamieson Mine area, are separated from the mine area by the "Canadian Jamieson" or "Highway" fault (Fig. KAM1). This fault has a dextral offset of approximately 1.5 km, determined by offset of mafic/felsic contacts and correlation across the fault of icelandite intrusions and related icelandite and high-iron, tholeiitic pillowed basalts. The Jamieson 12 outcrops (Fig. KAM6) occur approximately 1.5 km along strike from the mine and are interpreted to be lateral equivalents of the Canadian Jamieson Mine stratigraphy.

The Jamieson 12 outcrops are located in an area of transition from a subaqueous environment, represented by volcanic facies exposed in the Canadian Jamieson Mine area, to a shallow subaqueous and subaerial environment, represented by metavolcanic deposits exposed to the north. The mine sequence includes subaqueous, pillowed basalts, waterlain felsic tuffs, and felsic flow lobes with a carapace of fragmental debris, developed in response to interaction with sea water. To the north, the stratigraphy is dominated by thick, monotonous felsic tuff sections, felsic block and ash flows, interbedded with few, thin flows of pillow basalt. Welded lapilli are noted in both the tuffaceous and block and ash deposits. The thickness of the massive and pillowed basalt unit thins to the north across the Jamieson 12 area, whereas the felsic tuff beds pinch out south of the Jamieson 12 property.

The examination of outcrops (Fig. KAM6) commences in the west and proceeds up the stratigraphic section to the east.

7.1.7.1. Stop 3A

Exposed is the termination of a small rhyolite body into a unit of massive, felsic tuffs. The abrupt margins of the rhyolite against the tuff and the absence of associated fragmental carapace material indicate either that the flow was subaerial or this is the termination of a small intrusive lobe into thermally insulating tuffs. The felsic tuffs at this location contain juvenile lapilli fragments. The thickness of the tuff unit and the lack of internal structure suggest that this unit was deposited subaerially.

7.1.7.2. Stop 3B

The first indication of a subaqueous depositional regime on the Jamieson 12 property is

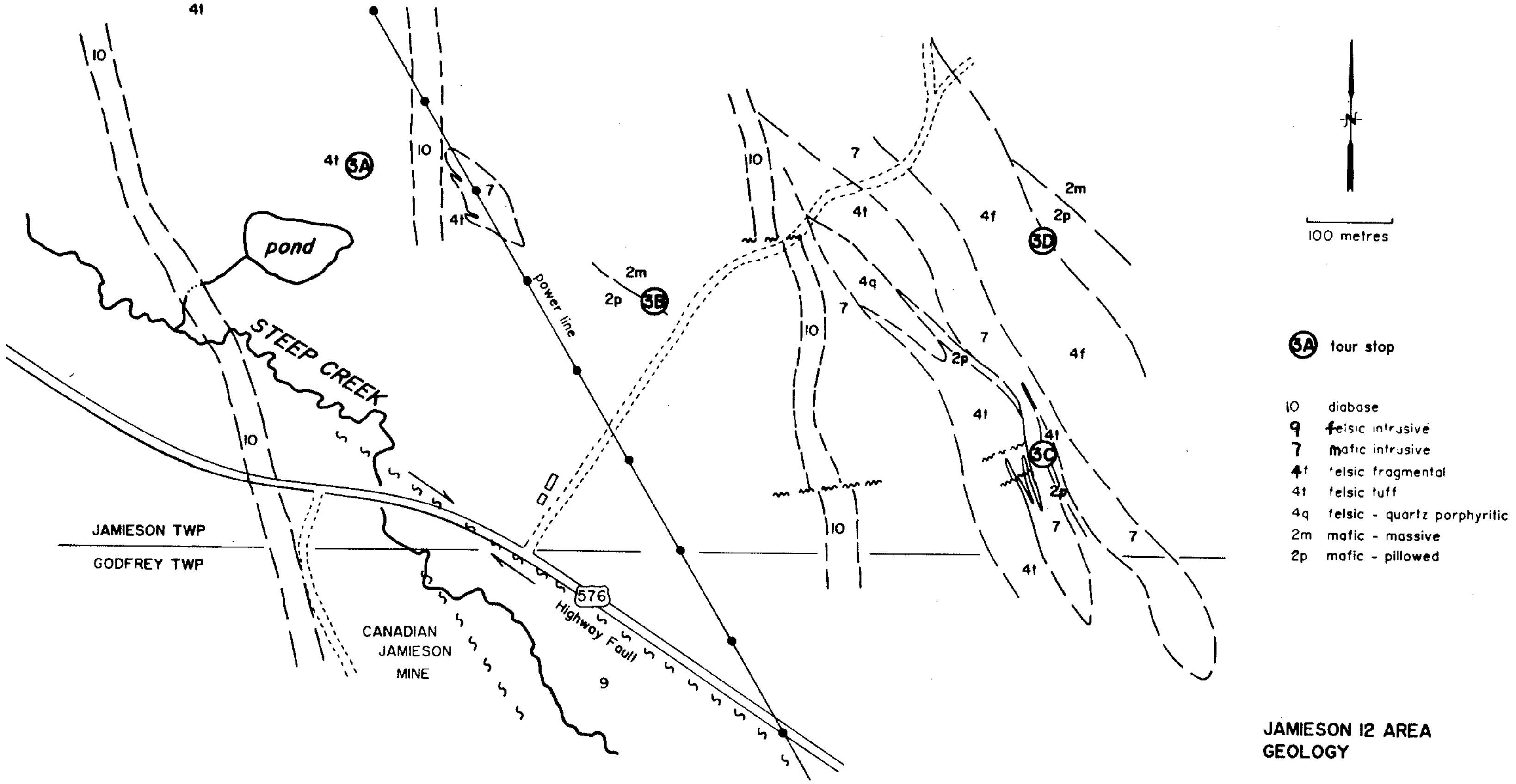

Figure KAM6: Simplified geology of the Jamieson 12 area, illustrating the location of tour stops.

manifest by a small outcrop of massive and pillowed, iron-rich tholeiitic basalt.

7.1.7.3. Stop 3C

Along a stripped outcrop ridge, welded felsic tuffs are intruded by a thick "icelandite" sill with numerous offshoots. The elevated abundances of P_2O_5 and TiO_2 in this sill provide an identical chemical signature to the icelandite flows that mark the upper boundary of mineralization at the Canadian Jamieson Mine. A wedge of metavolcanic rock that occurs between two of the sills, includes felsic tuff and a thin unit of sulphidized, iron-rich tholeiitic, pillow basalt.

7.1.7.4. Stop 3D

Northeast of Stop 3C, a thick sequence of lapilli to block sized felsic debris (a block and ash flow) is overlain by pillowed, icelandite flows. This felsic ash flow is correlated with a similar unit exposed two kilometres to the northwest. The mafic units, on the other hand, thicken to the southeast and cannot be reliably correlated north of these outcrops.

7.1.8. Discussion

A close spatial (temporal?) relationship exists between shallow-subaqueous to subaerial metavolcanic rocks and the ore deposits. This indicates that the precipitation of the sulphide mineralization took place in a shallow-subaqueous regime. Mineralization at, and proximal to, the northern deposits (Jameland and Kam-Kotia Mines; Fig. KAM1), may have been precipitated under deeper-water conditions, possibly accounting for the tonnage difference between the northern and southern deposits.

Kidd Creek Mine

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The deposit was discovered in 1963 using diamond drilling, based on an integrated regional geological and geophysical program. Ore was mined by open pit (Fig. KIDD1) from 1965 to 1979 and is now mined from underground via the # 1 and #2 shafts, each 930 and 1560 metres deep respectively. Ore between the 4600 and 5300 levels will be mined by access provided by an internal ramp (Fig. KIDD1). The #3 shaft, an winze, is currently under development to mine ore in the lower levels of the mine. This winze will begin at a depth of 1435 metres below surface, and will extend to a proposed depth of 2110 metres (Fig. KIDD1).

From the commencement of mining in 1966 to the end of 1989, approximately 85 million tonnes of ore have been milled, with an average millhead grade of 102 g/tonne Ag, 2.2 percent Cu, 7.2 percent Zn, and 0.28 percent Pb. Cadmium is recovered as a by-product, and construction of a plant which will recover indium is underway. Tin has also been extracted. As of December 31, 1989, proven and probable reserves above the 5600 foot level, diluted at ten percent nil grade, are 44.6 million tonnes with an average grade of 67 g/tonne Ag, 3.53 percent Cu, 5.08 percent Zn, and 0.16 percent Pb.

7.2.1. Regional Geological Setting

The Kidd Creek deposit is one of the largest volcanogenic massive sulphide deposits in the world. It is located in the west end of the Abitibi greenstone belt, 27 kilometres north of Timmins, Ontario.

The deposit occurs within an east-west striking, steeply dipping, assemblage of intercalated Archean ultramafic, mafic, and felsic metavolcanic and intrusive rocks, interlayered with minor accumulations of metasedimentary rocks. These rocks are assigned to the Kidd-Munro assemblage. The orebody is located in an area, characterized by anomalous, north-striking lithological contacts, at the top of a felsic metavolcanic unit which averages less than 100 metres in thickness away from the deposit, but which attains a thickness of 300 metres in the immediate mine setting (Fig. KIDD2). Stratigraphic units in the immediate mine area face to the west, and are overturned with dips of 70° to 80° to the east (Fig. KIDD3). Both the orebody and the surrounding country rocks attained greenschist facies metamorphism, associated with the development of a penetrative cleavage and linear fabrics. Brittle and ductile faults disrupt the continuity of lithological units and mineralization in plan and section at both regional and mine scales (Fig. KIDD4). Outcrop is sparse in the Kidd Creek area due to extensive Quaternary glacio-fluvial sediments and Recent swamp and stream deposits.

7.2.2. Mine Geology

Our understanding of the geology of the Kidd Creek deposit (Fig. KIDD2 and KIDD3) is the result of work by the staff of the Geology Department at Kidd Creek Mine over the past 25 years. Published descriptions of the geology of the Kidd Creek deposit include those of Walker and Mannard (1974) and Walker et al. (1975). The geology and geochemistry of the footwall rhyolites were described by Coad (1985). The oxygen isotopic characteristics of "fresh" and altered rocks in the Kidd Creek area are described by Beaty et al. (1988). The geochemistry of hydrothermal tourmaline and chlorite in the Kidd Creek Mine stratigraphy are described by Slack and Coad (1989).

The Kidd Creek orebodies are located near the stratigraphic top of a locally thickened, felsic metavolcanic unit. The portion of the felsic metavolcanic unit which stratigraphically underlies the

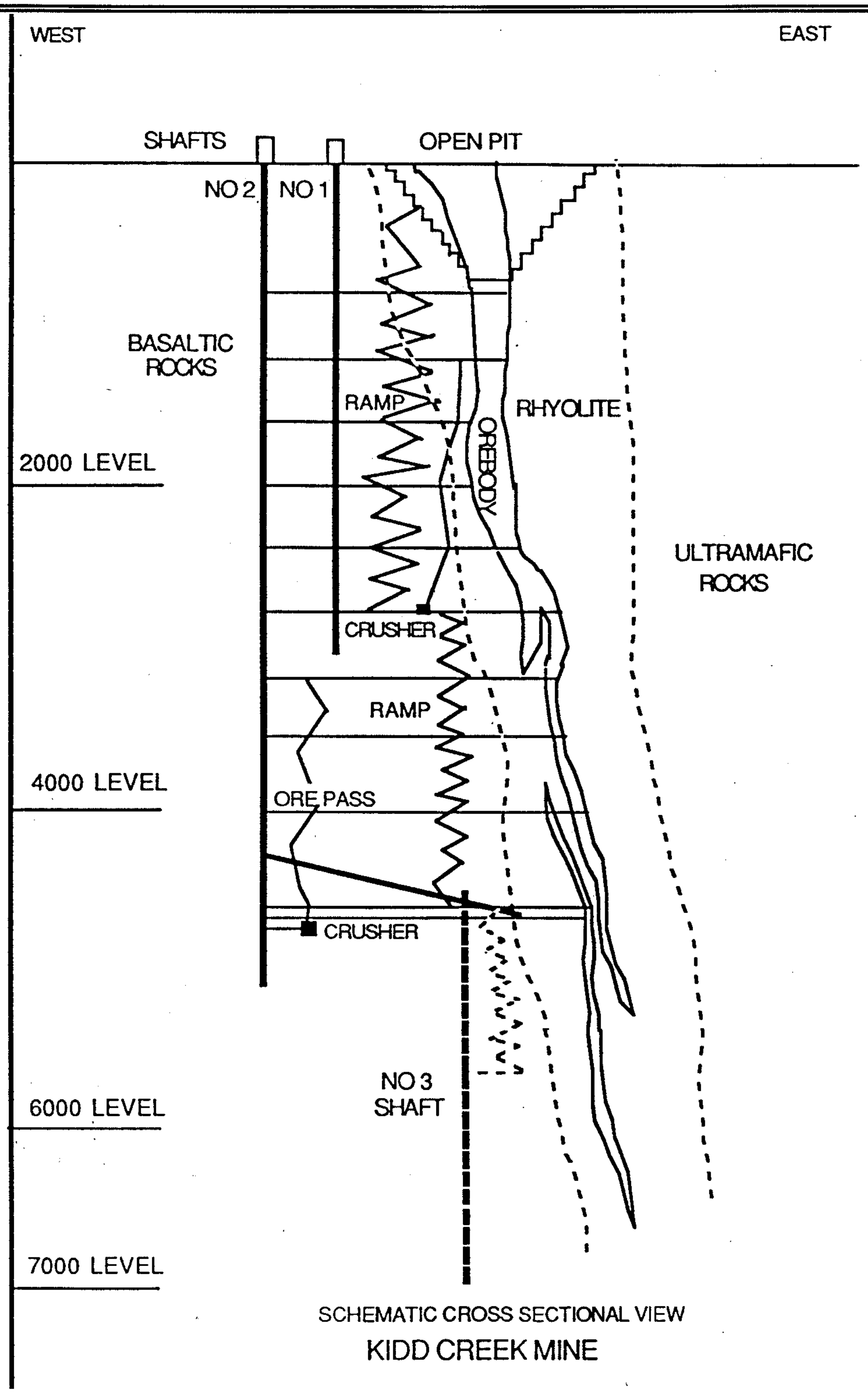
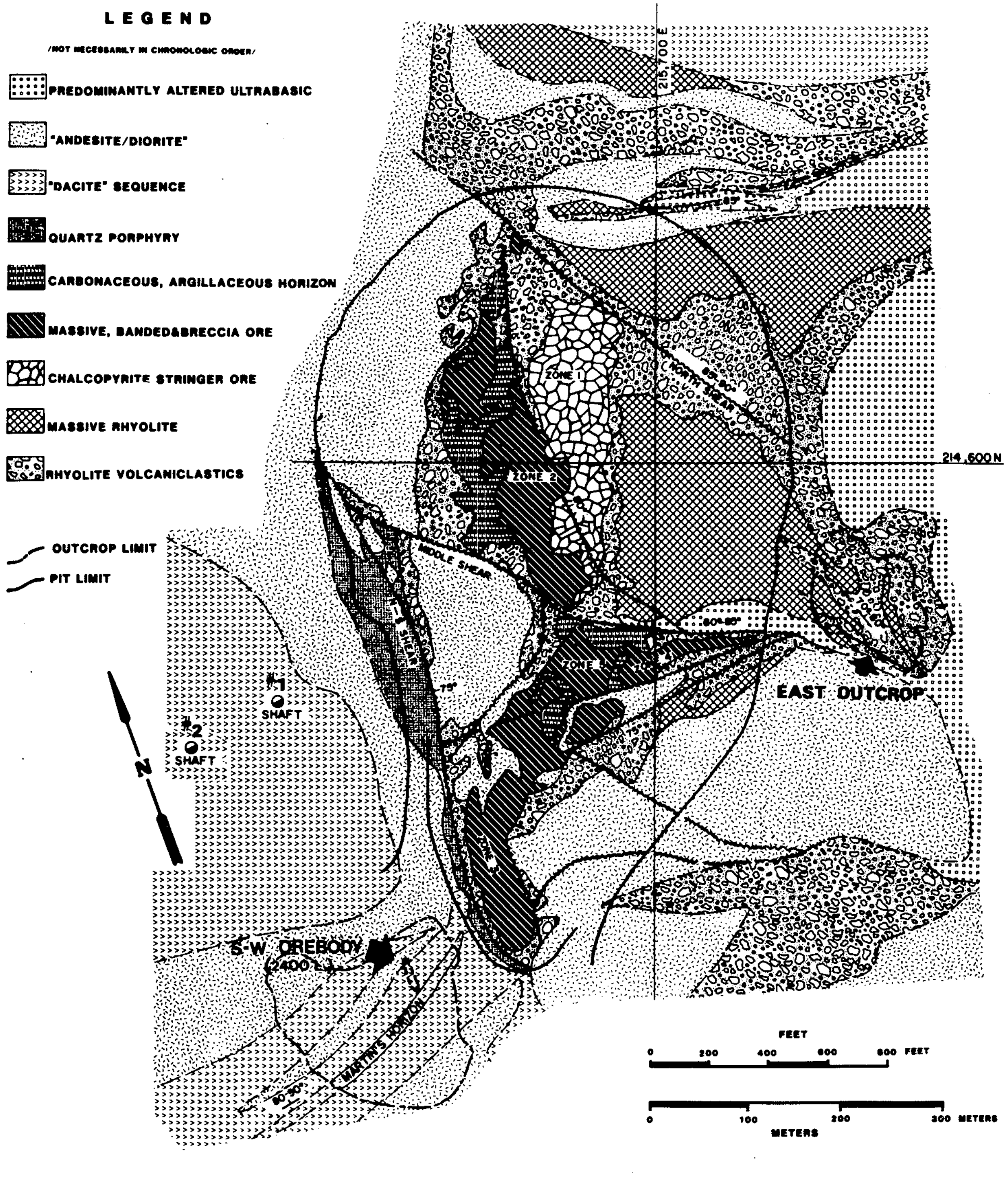


Figure KIDD1: Schematic, east-west cross section, looking north, throught the Kidd Creek Mine, illustrating the simplified distribution of rock types, the massive sulphide orebody, and the location of the open pit and shafts.



KIDD CREEK MINE SURFACE PLAN

Figure KIDD2: Simplified surface geology plan of the Kidd Creek Mine (after Walker and Mannard 1974).

orebodies consists of several distinct rock types, known informally, in mine nomenclature, as the "rhyolite volcaniclastics", "cherty breccia", and "massive rhyolite". A fourth lithology, known in mine nomenclature as "mixed rhyolite fragmentals", occurs at a position which is stratigraphically equivalent to the massive sulphide mineralization. These rhyolites and the massive sulphide mineralization are intruded by gabbro sills, called andesite-diorite in mine terminology, and bodies of serpentinized ultramafic rock. To the west, the stratigraphic hanging wall rocks consist of a carbonaceous metasedimentary unit, a quartz-porphyritic felsic unit, and pillowed mafic metavolcanic flows.

7.2.2.1. "Rhyolite volcaniclastics"

The "rhyolite volcaniclastics" consist of lapilli and block sized rhyolite fragments in a tuffaceous, rhyolite matrix. Degree of fragment sorting and rounding is highly variable, as is the relative abundance of tuff, lapilli, and blocks. Rhyolite fragments range in colour from yellow, grey, or black, reflecting varying degrees of sericitic, siliceous, and chloritic alteration, respectively. When viewed on fresh surfaces, in core or in underground exposures, these fragments appear massive. Fragments in weathered metavolcaniclastic rhyolites, exposed on surface, on the east side of the open pit, exhibit a range of textures. These rocks may represent, in part, the autobrecciated margins of the flow-dome sequence and, in part, pyroclastic deposits that surround the flow-dome sequence.

7.2.2.2. "Mixed rhyolite fragmentals"

Volcaniclastic rocks locally include fragments of pyrite, sphalerite, banded pyrite-sphalerite, and less common chalcopyrite, mafic flows ("dacite"), and carbonaceous argillite. These polymictic, metavolcaniclastic rocks are known as "mixed rhyolite fragmentals" in the mine terminology. Volcaniclastic rhyolites which contain sulphide clasts, are restricted to portions of the rhyolite assemblage which are stratigraphically equivalent to, or lie above, the massive sulphide orebodies. These rocks possibly represent debris flows (Walker et al. 1975).

7.2.2.3. "Massive rhyolite"

"Massive rhyolite" occurs as sills and dikes in the lower portion of the rhyolite assemblage east and northeast of, and stratigraphically below, the North Orebody stringer zone. "Massive rhyolite" is extremely siliceous and includes massive to flow banded subvolcanic intrusions, and intensely silicified metavolcaniclastic rhyolites, in which the primary metavolcaniclastic textures are no longer recognizable. Dykes of "massive rhyolite", cutting metavolcaniclastic rhyolite, are well exposed on the outcrop on the east side of the open pit. Bodies of "massive rhyolite" typically have dark grey to black, chloritic interiors and buff to yellowish-green, sericitic margins. Margins of "massive rhyolites" are commonly flow banded and brecciated. A light red colour, present locally, is attributed to the presence of disseminated sphalerite ("sphalerite dusting"). Conspicuous, white, subhedral albite and glassy, anhedral, quartz phenocrysts occur throughout the "massive rhyolites". This massive unit may represent the core of a flow-dome sequence.

7.2.2.4. "Cherty breccia"

"Cherty breccia" is the mine term for a light to medium grey, siliceous, aphanitic, intensely crackle-brecciated rhyolite. This unit occurs stratigraphically below the massive sulphide orebodies and it is commonly mineralized with stringers of chalcopyrite, pyrite, pyrrhotite, and sphalerite. The sulphide stringers, along with chlorite and iron-rich carbonate, fill fractures in the rhyolite. "Stringer ore" occurs where chalcopyrite stringers are abundant enough, over a large enough area in the "cherty breccia", to be mined as ore. The "cherty breccia" has been variably sericitized and chloritized. Fracture-controlled alteration has resulted in the presence of "speckle-textured cherty breccia". Flow-banding is locally present. This unit may represent the altered equivalent of the flow-dome sequence, although sharp intrusive contacts between massive rhyolite and "cherty-breccia" also exist.

7.2.2.5. "Carbonaceous horizon"

The "Carbonaceous horizon" is a lithologically variable metasedimentary unit which has a black, carbonaceous matrix. It occurs at or near the stratigraphic top of the North orebody massive sulphide lens, on the west side of Zone 2. Lithologies present in this unit include: 1) carbonaceous argillite; 2) finely laminated, carbonaceous argillite interbedded with pyrite and sphalerite; and 3) carbonaceous, polymictic, epiclastic breccias ("breccia ore").

7.2.2.6. "Andesite-diorite"

Three large masses of gabbro, termed "Andesite-Diorite" in the mine terminology, intrude the host rhyolites to the west, north, and southeast of the orebodies. "Andesite-Diorite-Type One" is massive, fine- to medium-grained, dark green to grey, and speckled with white to pink leucoxene grains up to two millimetres in size. A variety, known as "Andesite-Diorite-Type Two" is characterized by the presence of dark green, anhedral, femic phenocrysts up to one centimetre in size. These "Andesite-Diorite" bodies are roughly concordant to the rhyolites they intrude, and thus appear as sills which have separated a once contiguous assemblage of rhyolite into a number of separate, lens-shaped, rhyolite units. Narrow dikes and sills of "Andesite-Diorite" are also present within the orebodies and the host rhyolites. "Andesite-Diorite" masses located near the orebodies have been carbonatized to varying degrees (types three and four), indicating that, although post-ore, these gabbro intrusions were emplaced prior to cessation of hydrothermal activity.

7.2.2.7. "Quartz porphyry"

The westernmost, and stratigraphically youngest, rhyolite unit present in the mine workings is called the "Quartz Porphyry". It is a sericitic to chloritic, massive to tuffaceous rhyolite with local lapilli tuff sections. The "Quartz Porphyry" is characterized by the conspicuous presence of one to twenty five percent combined phenocrysts, one to four millimetres in size, of quartz and plagioclase. This rock unit is typically schistose, particularly in the more sericite-rich portions.

7.2.2.8. "Dacite"

Mafic metavolcanic flows, termed "dacite" in the mine terminology, stratigraphically overlie the rhyolite unit to the west and north. The flows are light to medium green, aphanitic to fine-grained, and have been bleached, carbonatized and sericitized. Massive, pillowed, and pillow-breccia facies are present within the mafic flows. Pillows are generally less than one metre in diameter, sparsely amygdaloidal, and have selvages less than one centimetre thick. Hyaloclastite is commonly present along pillow selvages and in pillow interstices. Black, carbonaceous argillite units up to ten metres thick, with or without pyrite and pyrrhotite, are locally present along flow tops. Carbonaceous material and pyrrhotite also occur locally between pillows. Massive portions of the flows appear lithologically identical to the "Andesite-Diorite-Type One" described above. The name "dacite" is derived from the bleached, light green colour and hardness of the mafic flows, which immediately overlie the rhyolite, relative to darker green, softer, more chloritic mafic flows distant from the rhyolite.

7.2.2.9. Serpentinite

A large mass of variably carbonatized serpentinite is present, east of the mine, in the stratigraphic footwall to the mine rhyolite package. It is black to dark green, dominantly massive, but both spinifex and cumulate textures are also present locally. Talc and carbonate are present in fractures. It is uncertain whether this serpentinite mass is composed of a package of komatiitic flows, which underlie the mine rhyolites, or whether the serpentinite is entirely or partly an intrusive peridotite body. Units of felsic and mafic metavolcanic rock are present within the serpentinite, and may represent intercalated metavolcanic units, or large xenoliths.

Light grey, carbonatized varieties of the serpentinite are known as "Talc Carbonate Rock" in the mine mapping. A thin tongue of "Talc-Carbonate Rock" extends west from this serpentinite body into the east side of the open pit. A similar elongate body of "Talc-Carbonate Rock" occurs just north of the open pit. Both of these altered serpentinite bodies occupy prominent east-southeast-striking shear zones.

7.2.2.10. Geochemistry

Many massive, base-metal sulphide deposits in the Superior Province are spatially associated with subaqueous, felsic metavolcanic rocks (Sangster 1972); however, not all felsic metavolcanic packages are mineralized. Several geochemical studies have been undertaken to test the hypothesis that a specific type of felsic metavolcanic rock is preferentially mineralized (e.g., Thurston 1981; Lesher et al. 1986).

Felsic metavolcanic rocks in the Kidd Creek Mine area are characterized as rhyolites and high-silica rhyolites, having relatively flat REE patterns ($[La/Yb]_n$ = 1-4), pronounced negative Eu anomalies (Eu/Eu^* = 0.20-0.61), low Zr/Y (2-6), high abundances of high field strength elements, and low abundances of Sc and Sr (Lesher et al. 1986).

7.2.2.11. Structure

The immediate mine area geology represents both a lithological and structural anomaly within the regional east- to northeast-striking metavolcanic-metasedimentary rock package. All lithologies in the mine, including the ore, have been subjected to complex folding and faulting. Overall strike of lithological contacts in the area of the open pit is north-northeast (Fig. KIDD2). The orebodies and their host rocks dip 70° to 80° east and are overturned (Fig. KIDD3).

The dominant cleavage present in the mine strikes southeast and dips 75° northeast. A second cleavage strikes east and dips 80° north. The intersection lineation of these two cleavage planes plunges 75° to 80° northeast, parallel to the plunge of the axis of greatest linear elongation of the orebodies. The intensity of cleavage is locally variable, and appears to be a function of both lithology and alteration intensity and type. Sericite-rich and talc-rich rocks in particular commonly exhibit moderately to strongly developed cleavage.

Brittle gouge-filled faults, and "shear zones" (zones of intense cleavage) are both present in the Kidd Creek Mine. Cleavage and brittle faults both deform mineralization, and thus post-date ore. The "North-South Shear Zone" and the "Middle Shear" are the most prominent shear zones in the mine.

The "North-South Shear Zone" approximately follows the contact between the "Quartz Porphyry" and the "Wedge Andesite-Diorite" on the east side of the "Quartz Porphyry" (Fig. KIDD2). It is a zone of strong cleavage, up to 18 metres wide, localized predominantly in sericitized "Quartz Porphyry". A parallel structure, known as the "North-South A Shear Zone", is localized along the eastern edge of the "Wedge Andesite-Diorite" where it is in contact with the "mixed rhyolite fragmentals" which overlie the orebody. Both these structures have a north strike and dip 75° east.

The "Middle Shear" is a zone of intense cleavage and faulting up to 30 metres wide that separates the "North" and "South" orebodies. It has a west to northwest strike and dips 80° to 85° north (Fig. KIDD2).

South-dipping faults exhibit a reverse, left-hand sense of displacement. These faults strike east-southeast and dip 75° to 85° south. They are filled with gouge and/or quartz-calcite veins. Slickensides on the fault surfaces plunge 75° northwest. The south-dipping faults offset all rock types in the mine, including the orebodies (Fig. KIDD4). They also crosscut and drag-fold the post-ore cleavage. Vertical offset is interpreted to be approximately 200 metres along each of these structures. The horizontal component of movement is minor.

The Gouge Fault strikes north-northwest, dips 55° to 65° northeast, and is localized in the "Andesite-Diorite" and rhyolite, situated west of the orebodies. The Gouge Fault has an apparent left-hand, normal sense of offset. It is filled with up to five centimetres of gouge and fault breccia. Subhorizontal joints, commonly filled with quartz-calcite veins, occur in the wall rock adjacent to this fault. The Gouge Fault commonly occurs as two or more closely spaced, anastomosing faults. This system of anastomosing faults, subhorizontal joints, and associated steeply dipping cleavage can create incompetent ground over widths of up to ten metres.

7.2.3. Mineralization

There are three major types of ore within the Kidd Creek deposit: 1) stringer ore; 2) massive, banded, and bedded sulphides; and 3) sulphide breccia ore.

7.2.3.1. Stringer Ore

Stringer ore is characterized by irregular chalcopyrite-filled stringers hosted in a pale to dark grey, crackle - brecciated rhyolite. Chalcopyrite content of the stringer ore varies from three to thirty percent, but averages five or ten percent. Individual stringers are generally less than two centimetres wide, but are locally up to one metre wide. Pyrite and/or pyrrhotite occur with the chalcopyrite or occur alone in uneconomic stringer sulphide zones. Pyrrhotite content of the stringer ore increases below the 2300 foot level (1000 metres vertical depth). Sphalerite usually comprises between 0.1 and 1.0 percent of the stringer sulphide ore, and can be present as stringers and disseminated as a reddish-brown staining of the rhyolite host rocks. It is most abundant on the margins of the stringer chalcopyrite mineralization, particularly in the stratigraphic footwall of the stringer chalcopyrite orebodies.

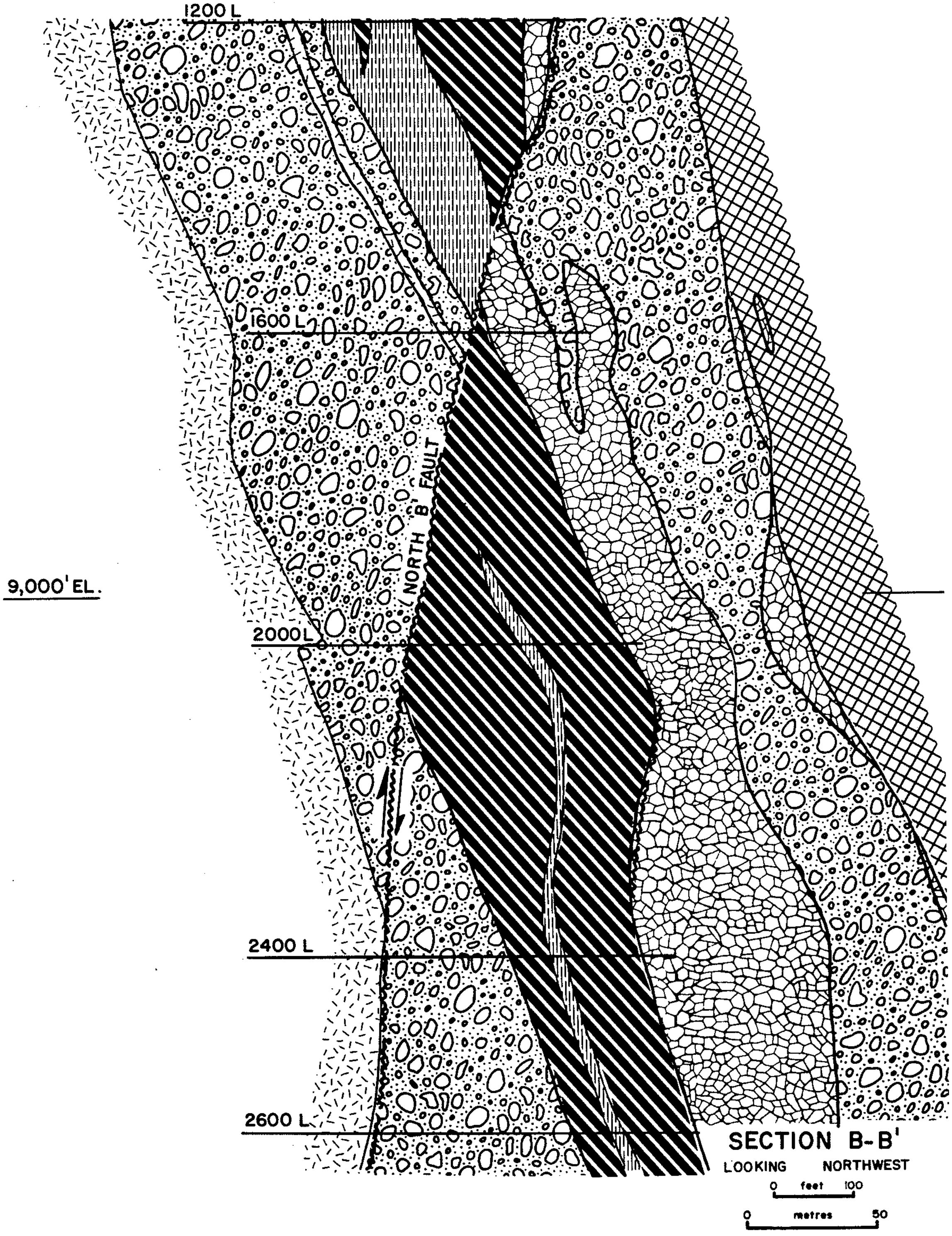


Figure KIDD3: Simplified east-west cross-section, along 214,600 N (see Fig. KIDD2), looking north, through the Kidd Creek Mine (Walker and Mannard 1974). Geology as in legend depicted on figure KIDD2.

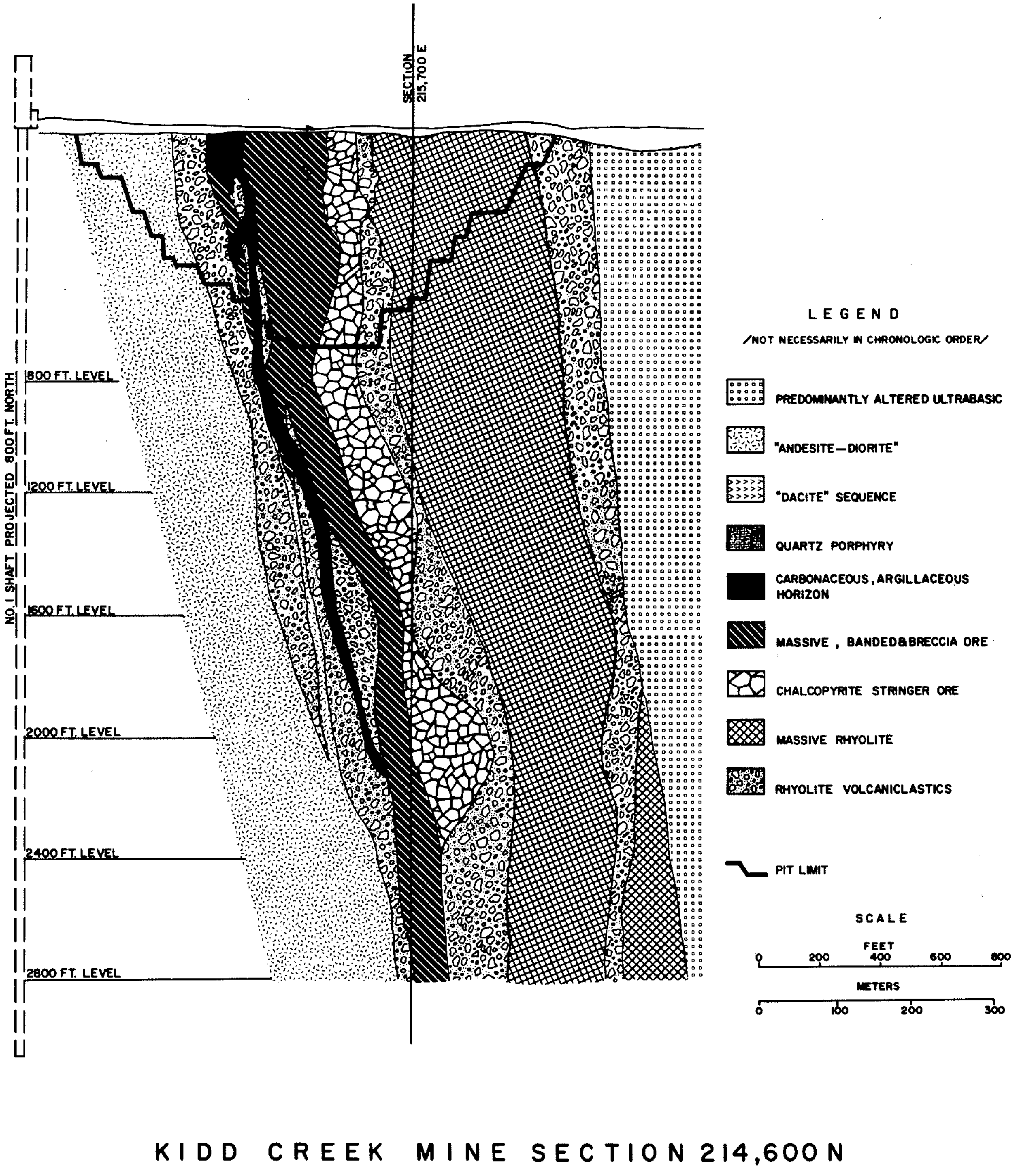


Figure KIDD4: Simplified section along 214,600 N (see Fig. KIDD2) through the Kidd Creek Mine, illustrating the effects of late faulting.

7.2.3.2. Massive, Banded, and Bedded Ores

Massive, banded, and bedded ores stratigraphically overlie the stringer ore. This ore type varies in composition and texture from homogeneous, almost monomineralic pyrite, sphalerite, or chalcopyrite, to banded mixtures of pyrite, sphalerite, pyrrhotite, chalcopyrite, and galena. Rhyolite host rocks and gangue minerals comprise up to 50 percent of this ore type. Layers of massive or banded sulphides are locally intercalated with layers of metavolcaniclastic rhyolite, or with carbonaceous argillite.

7.2.3.3. Sulphide-breccia Ore

Sulphide-breccia ore consists of fragments of pyrite and/or sphalerite within carbonaceous argillites and metavolcaniclastic rhyolites situated at the stratigraphic top of the orebodies. Variable proportions of poorly sorted fragments of rhyolite, sulphide, basalt, and carbonaceous argillite are present in these chaotic, epiclastic breccias. Sulphide fragments are as large as a few metres across. Proportions of sulphide fragments present are highly variable over short distances, and the abundance of sphalerite fragments determines whether or not this lithology is mined. Chalcopyrite fragments are generally absent. These ores are interpreted to have been transported and deposited as debris flows.

Finely interbedded pyrite, sphalerite, and carbonaceous argillite occur at the same stratigraphic level as the sulphide-breccia ores, both interbedded with the breccia ore and as lateral facies equivalents to it. Individual beds are generally less than one centimetre thick, but range up to five centimetres in thickness. Locally, primary sedimentary textures such as load casting, flame structures, scours, and graded bedding are preserved. The sulphide beds may be composed of only pyrite or sphalerite, or of homogeneous to graded mixtures of pyrite and sphalerite.

7.2.4. Characteristics of Ore Types

The main Kidd Creek deposit is divided into the North and South orebodies. A small sulphide lense, known as the Southwest orebody, is also present. The ores are further subdivided for the purposes of computer modelling and ore reserve estimation into five zones. Each zone is defined by a particular combination of spatial, structural, host-rock, and ore-type parameters. The orebodies at Kidd Creek possess patterns of metal zoning characteristic of volcanogenic massive sulphide deposits.

7.2.4.1. Mineral Distribution

Copper is most abundant in the stringer ores and the basal portion of the massive ores. Zinc is most abundant in the massive, bedded, and banded sulphides which stratigraphically overlie the copper-rich ores. Silver, lead, tin, and cadmium are relatively enriched in pyrite-sphalerite ores. Indium and selenium are relatively enriched in copper-rich ores, and enriched in the bornite zone, which is described below. Silver occurs dominantly in the native form, lead occurs as galena, and tin occurs predominantly as cassiterite.

7.2.4.2. North Orebody

The North orebody strikes north-northwest to north-northeast, is overturned and dips 80° east. It has been defined by development and diamond drilling from surface to a vertical depth of 1700 metres (5600 level). Current deep diamond drilling is aimed as defining the extension of this orebody below 5600 level. The North orebody is divided into two zones based on ore type. Zone One, which constitutes the eastern portion of the North orebody, is the largest, most continuous area of chalcopyrite ore in the mine.

Zone Two is composed of massive to semi-massive pyrite and sphalerite with well developed banded and fragmental textures. It is the most pyritic of the ore zones, averaging 55 percent pyrite. The highest contents of lead, silver, and tin in the mine occur in sphalerite ore on the southwest side of Zone Two. Sulphide breccia ore is mined from the west side of Zone Two. The contact between zones one and two is sharp. Lenses of massive chalcopyrite commonly occur along this contact.

7.2.4.3. South Orebody

The South orebody extends from surface to a vertical depth of 1040 metres, with its bottom just below the 3400 level. It is subdivided into zones three, four, and five. Zone Three strikes north-northeast, is overturned and dips 70° east. It consists mainly of massive sphalerite, pyrite, and chalcopyrite. Sulphide banding is locally present at the margins of this zone. Metal zoning is poorly developed.

Zones four and five consist of banded pyrite, sphalerite, and chalcopyrite interlayered with metavolcaniclastic rhyolites. Zone Four has a strike of east-southeast, and a dip of 80° north. Zone Five is overturned, and has a strike and dip similar to Zone Three.

7.2.4.5. Bornite Zone

A discontinuous area of high-grade copper mineralization, known as the Bornite Zone, occurs on the stratigraphic footwall of the South orebody, between 1200 and 2800 levels (365 to 850 metres vertical depth). This mineralization consists of semi-massive to massive bornite, chalcopyrite, tennantite, and pyrite hosted in a fragmental-textured rhyolite. The Bornite Zone is enriched in Ag, As, Bi, Co, In, and Se, the most important of which is silver. Silver tenors up to 4450 g/t (130 ounces per ton), over 1.5 metres, have been obtained with minor associated gold values.

7.2.4.6. Southwest Orebody

The Southwest orebody is a massive sulphide lense which was discovered in 1977. It is located southwest of the South orebody. The orebody, which has subsequently been mined, extended from 2600 level (785 metres vertical depth) to the 3200 level (975 metres vertical depth). It consisted of pyrite, sphalerite, galena, and silver, but was devoid of copper mineralization. Subeconomic mineralization has been defined up to the 2400 level (725 metres vertical depth), and down to the 3600 level (1080 metres vertical depth). The width of the massive sulphide lense varied from two to 20 metres. The Southwest orebody is interpreted as the distal equivalent to the more proximal South and North orebodies.

7.2.5. Rock Alteration

Synvolcanic alteration minerals have been subsequently metamorphosed, so the mineralogy of altered host rocks described below does not necessarily represent the original alteration mineral assemblages.

Rhyolites within the stringer zone are intensely crackle-brecciated, and alteration is strongly fracture-controlled. These rhyolites are depleted in Na_2O, K_2O, CaO, and Al_20_3, but are enriched in FeO, MgO, and SiO_2 relative to stratigraphically equivalent rhyolite outside the stringer zone. This alteration chemistry is expressed mineralogically by the destruction of feldspar, and by varying degrees of silicification, chloritization, and sericitization. Sericitic rhyolite has higher Al_2O_3 and K_2O abundances with respect to chloritic rhyolites. Iron-rich carbonate minerals are present both in the stringer zone, and within the massive sulphides.

Both iron-rich and magnesium-rich chlorites occur at Kidd Creek (Slack and Coad 1989). Iron-rich chlorites occur within the stringer sulphide zone, whereas more magnesium-rich chlorites occur generally outside the zone of stringer mineralization. The formation of iron-rich chlorites is attributed to high temperature, iron-rich hydrothermal fluids, whereas the formation of the magnesium-rich chlorites is attributed to the influx of cooler, magnesium-rich seawater (Slack and Coad 1989).

7.2.6. Temporal Constraints

The Kidd Creek rhyolite, footwall to the mineralization, has a U-Pb zircon crystallization age of 2717 +/- 2 Ma (refined age reported by Barrie and Davis 1990, using an abraded fraction from Nunes and Pyke 1980). This represents the age of the rhyolitic rocks which are host to the massive sulphide mineralization at the Kidd Creek Mine. A tuffaceous rhyolite from Prosser Township, located to the east of the Kidd Creek Mine, has an identical age of 2716 +/- 4 Ma (Barrie and Davis 1990).

7.2.7. Tour Guide

A list of definite tour stops cannot be given at the time of writing, due to the necessity of altering underground tour routes to conform to mining activities at the time the tour is given. A proposed tour itinerary is given below.

Stop 1.
Slide show.

Proceed underground:

Stop 2.
Chalcopyrite stringer ore.

Stop 3.

Massive sulphide ore.

Stop 4.

South-dipping post-ore fault.

Stop 5.

Carbonaceous polymictic sulphide breccias.

Stop 6.

"Andesite-Diorite"

Stop 7.

"Quartz porphyry"

Stop 8.

"Dacite"

Return to surface:

Stop 9.

Diamond drill core and display specimens.

Stop 10.

Massive and metavolcaniclastic rhyolites on the East Outcrop.

LODE GOLD

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The Timmins area is perhaps best known as a gold mining camp (Porcupine camp), from which about 1780 tonnes of gold have been produced (Table 1). The purpose of this chapter is to provide descriptions of some of the gold deposits in this camp (Hollinger-McIntyre-Coniaurum, Dome, Pamour #1, Hoyle Pit, Hoyle Pond, and Bell Creek - Marlhill Mines), associated rock types, the types of attendant rock alteration, and local structural features which bear on the localization and timing of the gold quartz vein systems. Auriferous quartz veins post-date the 2700 Ma felsic metavolcanic rocks and cut the 2686 Ma felsic porphyries. The gold mineralization occurs within or adjacent to zones which had experienced complex structural and alteration histories. Tour stops are provided where possible, but, because of the active mining, not all mines could provide definitive stop descriptions far in advance of the planned visit.

Gold mineralization in three geographic areas within the Porcupine camp will be examined. Within the core of the Porcupine camp, mineralization at the Dome and Hollinger-McIntyre-Coniaurum Mines occurs in a sequence of altered and deformed iron-rich tholeiitic basalt and komatiites. Intrusive, 2691 to 2688 Ma (Corfu et al. 1989; Marmont and Corfu 1989) quartz-feldspar porphyries constitute an important component of this mineralized area. Although operated as three different mines, the Hollinger-McIntyre-Coniaurum system can be viewed as a single mineralized zone. Similarly, several mines occur in proximity to the Dome Mine, and in a general sense, that area can be viewed as a single mineralized system. Approximately 60 percent of the gold from the Porcupine camp came from the Hollinger, McIntyre, Coniaurum, and Dome Mines (Table 1).

In the northeastern part of the Porcupine camp, gold was mined from several properties, including the Broulan, Hallnor, Pamour #1, and the Hoyle Mines (Fig. 2). The geological setting of this area differs somewhat from that represented in the central part of the Porcupine camp. Auriferous quartz veins cut basaltic and ultramafic komatiitic flows, magnesium-rich tholeiitic basalt, and metasedimentary wacke, arkose, and slate of the Timiskaming assemblage. Felsic porphyritic intrusions are absent from this sequence.

Mines in the northern part of the Porcupine camp (Bell Creek - Marlhill, Hoyle Pond, Bell Creek) represent relatively recent discoveries. In this area, gold-quartz veins cut iron- and magnesium-rich tholeiitic basalt, ultramafic komatiites, and carbonaceous interflow metasedimentary rocks. Although felsic porphyritic intrusions are present in the mine sequences of at least the Hoyle Pond and Bell Creek, the porphyries constitute only a very minor component of the mine stratigraphy.

Dome Mine

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The Dome Mine was discovered in 1909 by a party of prospectors, headed by John S. Wilson, who found a spectacular showing of gold on a dome-shaped outcrop of quartz approximately two miles southwest of the shores of Porcupine Lake. A total of four claims were staked on the showing which later became the "DOME MINE". More than 75 years of continuous mining activity at the Dome has gradually disclosed a complex geological picture and the presence of ore deposits in a block of ground approximately 3.5 kilometres long, 1.8 kilometres wide, and 1.8 kilometres deep. Gold-bearing ore bodies occur in several different rock types and in many different structural settings. To the end of 1987, the gold operation has produced a total of 353.3 tonnes (11,359,348 million ounces) of gold and 62.4 tonnes (2,004,985 million ounces) of silver from milling a total of 45,578,900 million tonnes of ore for a total production value of $924,865,548. Aspects of the Dome Mine geology have been discussed by Holmes (1968), Rogers (1980, 1981, 1984), and Moritz (1988).

8.1.1. Regional Geological Setting

Gold mineralization occurs in iron-rich tholeiitic metavolcanic rocks which comprise part of the Tisdale assemblage (historically called "Vipond series"; Ferguson et al. 1968) and clastic metasedimentary rocks which comprise parts of the Porcupine and Timiskaming assemblages. Comprehensive descriptions of the rocks which comprise the "Vipond series" are given in Section 8.2.2.3.

8.1.2. Detailed Geology

The Dome Mine lies on the south limb of the large-scale, Porcupine Syncline in an area where Archean ("Keewatin") metavolcanic rocks are overlain by Timiskaming-like metasedimentary rocks. At the mine site, the local sequence of metavolcanic and metasedimentary rocks have been folded to form a northeasterly plunging structure, referred to as the "Greenstone Nose" (Fig. DOME1). Immediately south of the metasedimentary sequence lies an east-northeast-striking, highly strained zone in which magnesium rich, carbonatized rocks occur. The highly altered zone corresponds to the trace of the ductile Dome fault, interpreted to represent a branch off the main Porcupine-Destor Fault. To the west, the highly altered zone passes between two major porphyritic intrusive bodies- the Paymaster and Preston "porphyries". The zone then grades through a chlorite- and talc-rich assemblage before joining with the main Porcupine-Destor Fault. To the east, lenses of porphyry-type rocks, similar lithologically to the main porphyry bodies, occur within the highly altered zone. The eastern extremity of the zone is similarly represented by chlorite- and talc-rich assemblages before being truncated by the Burrows-Benedict Fault.

To the south of the Dome fault ("the highly altered - porphyry zone") are the "South Greenstones", a south-dipping assemblage consisting of massive and pillowed flows, more mafic than the flows of the "Greenstone Nose". Their anomalous south dip suggests that a major structural break exists along the Destor-Porcupine deformation zone, which dips steeply north and which is identified by a well marked talc-chlorite zone. This zone passes about one kilometre south of the mine workings (Fig. DOME2).

8.1.3. Structure

The main structural feature in this area is the Porcupine Syncline. The fold style of the Porcupine Syncline has been discussed by Roberts (1981) and Hodgson (1983). Roberts (1981) noted that there is no penetrative fabric axial planar to the Porcupine Syncline, and therefore, the syncline appears to have developed prior to the deformation event which imparted the foliations and lineations to the rocks in

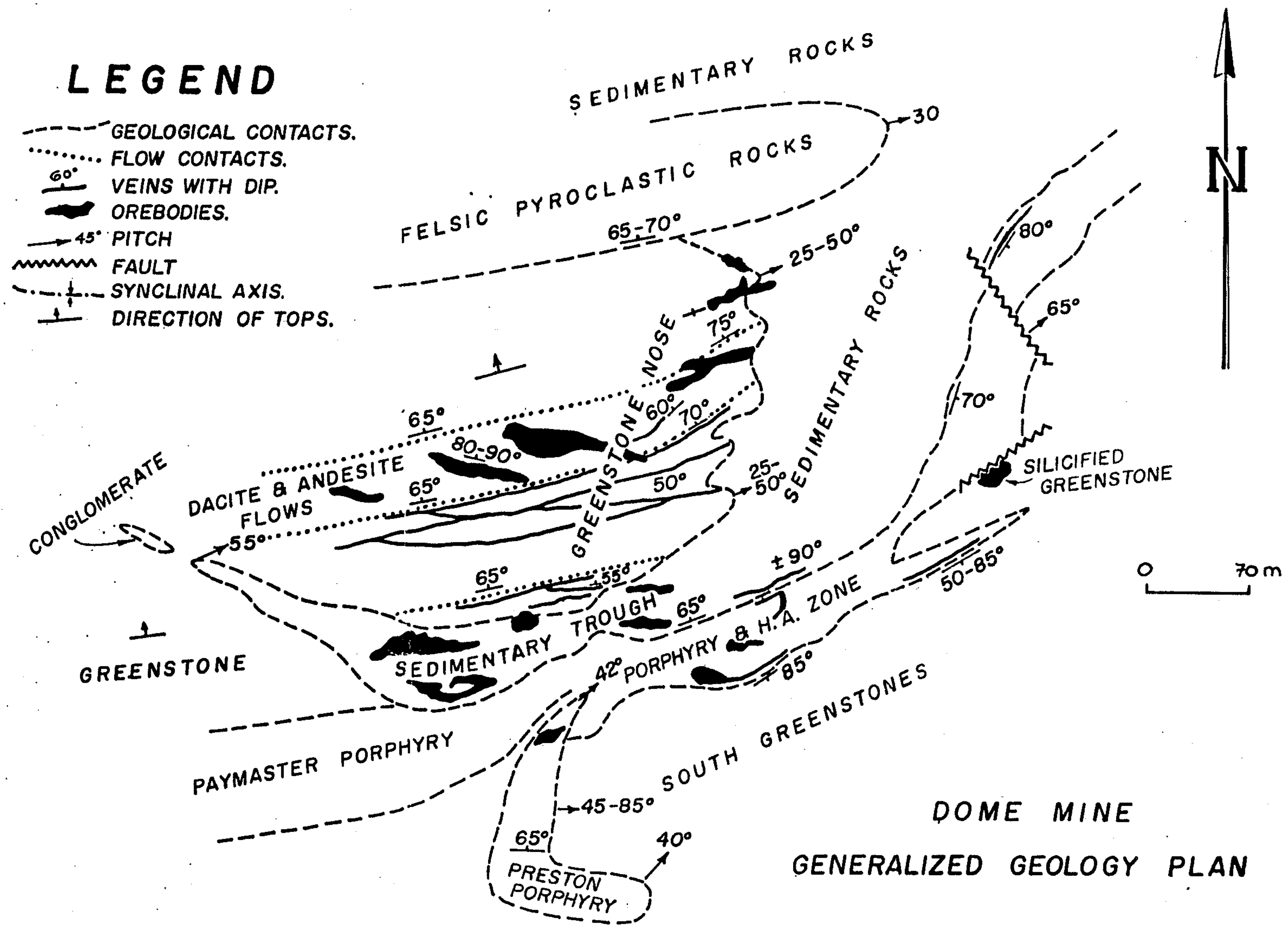
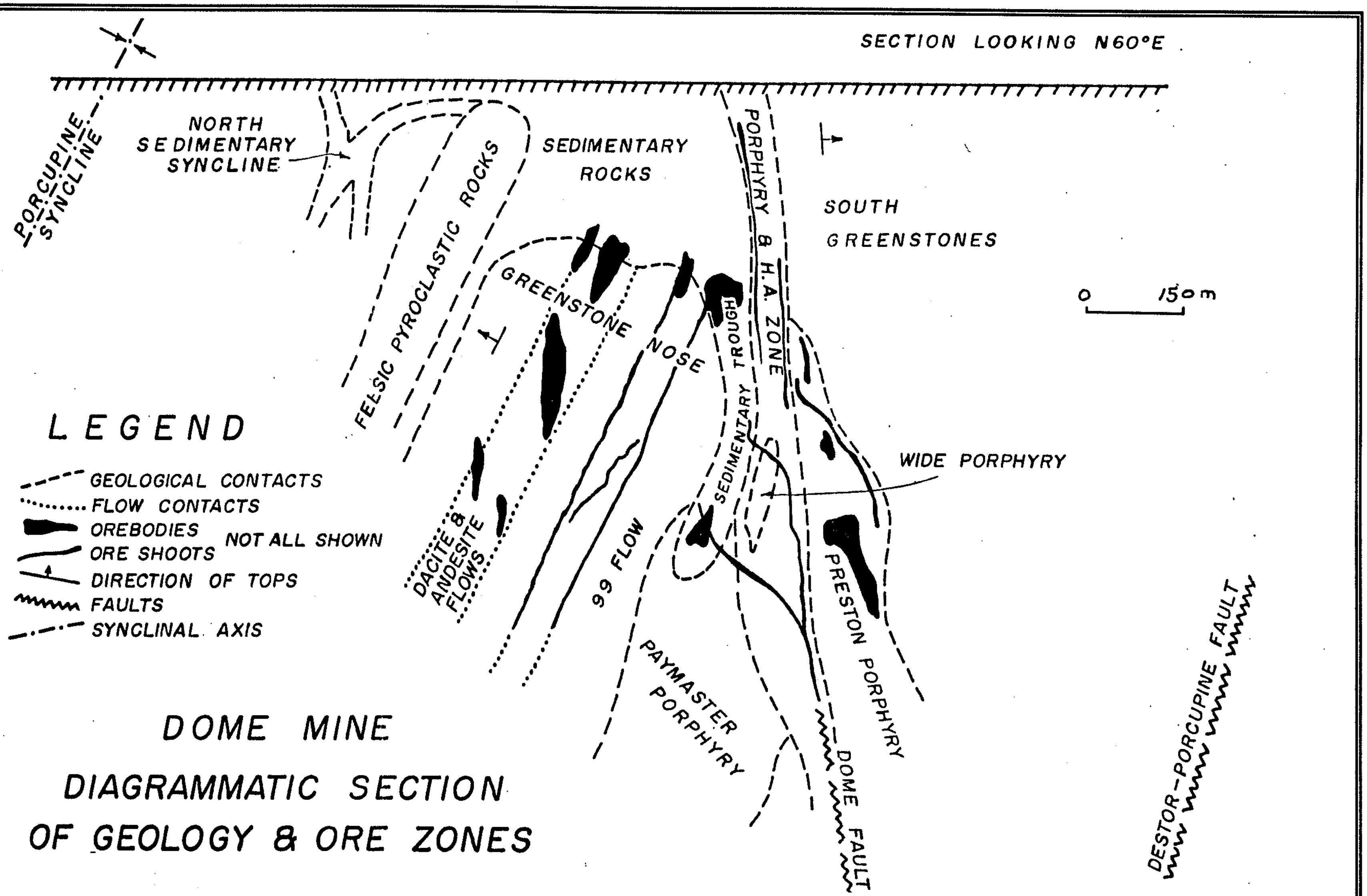


Figure DOME1: Diagrammatic geological plan of the Dome mine underground.



DOME MINE

DIAGRAMMATIC SECTION
OF GEOLOGY & ORE ZONES

Figure DOME2: Diagrammatic geological section through the Dome Mine, illustrating the location of specific types of mineralized zones, the Dome fault, and the Destor-Porcupine deformation zone.

the Timmins area. The south limb of the Porcupine Syncline has been locally truncated by the Dome fault. Associated with the regional penetrative foliation in the Timmins area is a northeast, moderately plunging (-55^{o}) extension lineation (Ferguson et al. 1968; Roberts 1981; Hodgson 1983). As suggested above, the Dome fault appears to merge with the Destor-Porcupine deformation zone at depth. The Dome fault deforms felsic porphyritic intrusions, which elsewhere in the Porcupine camp have been dated at 2691 to 2688 Ma (Corfu et al. 1989; Marmont and Corfu 1989).

8.1.4. Mineralization

Several styles of mineralization are recognized in the Dome Mine. Some styles are preferentially developed in particular rock types (Fig. DOME3). The following is a brief description of the styles of mineralization observed in the Dome Mine:

Type I: Long narrow veins in schist parallel to the general trend of the formation.

a) Ankerite veins (in the "Greenstone Nose");

b) Quartz-tourmaline veins (chiefly in highly altered rocks);

c) Fuchsite vein (in highly altered rocks).

Type II: Lenticular or irregular "tension" veins in massive rocks or crossing the schistosity in schistose rocks. They cut Type I veins:

a) Orebodies of veins arranged en echelon in massive lavas in the "Greenstone Nose";

b) Stockworks, chiefly in the sedimentary trough and generally in conglomerate;

c) Stockworks in porphyries and associated highly-altered wall rock.

Type III: Mineralized rock, in which the gold is associated with pyrite and/or pyrrhotite and in which there is little or no vein material:

Type IV: Silicified Greenstone

At least three ages of quartz veins contain gold mineralization, whereas at least two other quartz carbonate vein systems appear to be post-ore. In addition to the multi-stage nature of the gold mineralization, it is acknowledged that remobilization of some of the gold has taken place as well. The effect of this remobilization, and the processes which were responsible for it, have had a marked influence on the ores, and more particularly, on those within the sedimentary environment. Primary sedimentary features, however, have been all but masked by later tectonic deformation.

Gold occurs primarily as coarse native metal in quartz or ankerite-type veins. Several tellurides, namely, altaite, petzite and tellurobismuthite, have been recognized in the mine; however, they constitute a very minor source of the total gold production. Silver is recovered as a by-product of the operation in the ratio of about one ounce of silver to six ounces of gold. Sulphides, present in all the ore-types, average about two to three percent. Pyrite and/or pyrrhotite are the dominant sulphides; however, chalcopyrite, sphalerite and galena are found locally in most ore-types and are quite good indicators of gold content. Scheelite is found in minor quantities, predominantly in association with the "porphyry ore". In one particular zone, arsenopyrite is sparsely disseminated in the silicified greenstone-type ore.

8.1.5. Rock Alteration

Rock alteration generally associated with the mineralized zones includes replacement by ferroan carbonate, white mica (sericite), fuchsite, and silica (Fryer et al. 1979). Hydrothermal albite can occur within and immediately adjacent to quartz veins.

8.1.6. Temporal Constraints

Gold mineralization at the Dome shows a marked spatial association with the two most significant "structural" features within the mine, namely the Greenstone Nose and the Highly Altered Zone. Paradoxically, the former may represent the expression of an erosional surface, while the latter represents a deformed, ultrabasic flow.

This gold mineralization exists as hydrothermal quartz veins and possibly as a syngenetic, gold-enriched precursor, manifest as a chemically precipitated sediment along with cherty and ferroan dolomite (Ankerite) beds in the mafic metavolcanic sequence. The presence of the

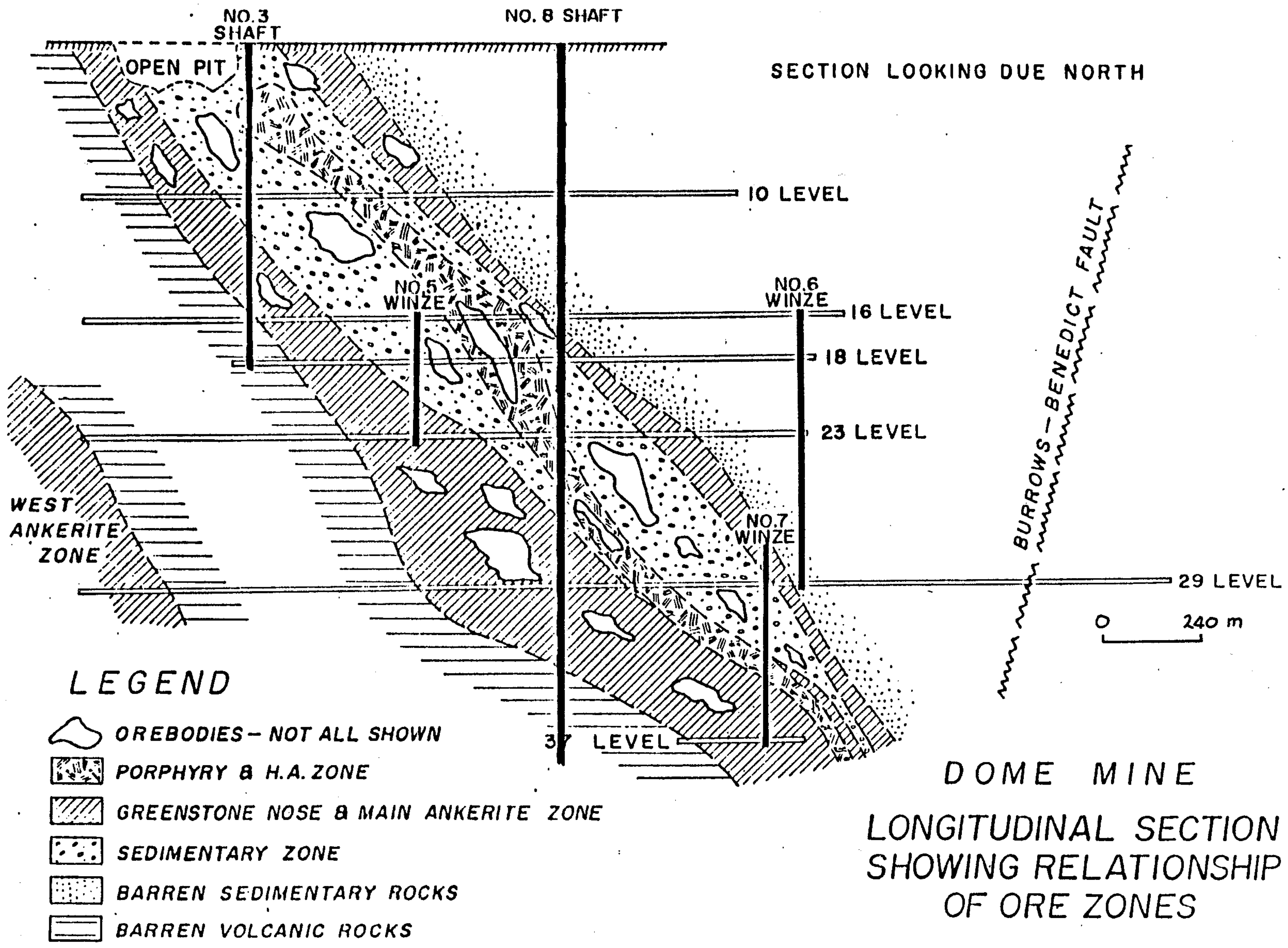


Figure DOME3: Generalized longitudinal section through the Dome Mine illustrating the location of some of the ore zones.

controversial syngenetic mineralization accounts for those ore bodies which seem to be confined within specific stratigraphic boundaries (e.g. ankerite and tuffaceous-type ore). The existence of syngenetic gold mineralization in some of the mines in the Porcupine camp was debated in the late 1970's (e.g., Fryer and Hutchinson 1976; Karvinen 1978; Kerrich and Fryer 1979; Fyon and Crocket 1982). These observations have been questioned by subsequent workers (e.g., Hodgson 1983; Fyon et al. 1986). In the Dome Mine, ankeritic units, within sequences of iron-rich tholeiitic basalt, represent the inferred syngenetic material (Fryer et al. 1979; Kerrich and Fryer 1979). The origin of these units has also been questioned and they have been re-interpreted as shear-localized, quartz-ankerite veins (Roberts and Stevens 1989). Associated quartz vein mineralization formed in response to later tectonic processes.

Examples of quartz-vein ore deposits include those of the "highly altered" carbonate rock zone, the long sinuous quartz-tourmaline veins, associated with drag folding in the porphyries, and the fracture-filling auriferous quartz veins emplaced in the "dacite-type" ore.

Felsic porphyritic intrusions in the Timmins area have been dated, in an attempt to constrain the age of auriferous quartz veins, which cut the porphyries. The Preston and Paymaster porphyries, in the area of the Dome Mine, have an age of approximately 2690 Ma (Corfu et al. 1989), which provides the maximum age of gold-quartz vein mineralization. Hydrothermal sericite from these porphyries has a $^{40}Ar/^{39}Ar$ age of 2633+/-6 Ma (Masliwec et al. 1986). While this mica age is representative of some thermal event, it cannot be unequivocally related to the precipitation of gold; hence, it can only be stated that gold-quartz veins in the Dome Mine formed following the emplacement of the felsic porphyritic intrusions.

8.1.7. Tour Guide

STOP 1: 1272 #1 cross cut (X/C) - 1257 Drive (Dr.). "Dome Key Flow" 31 South - pillowed lava showing the coalescing nature of the spherulites (variolites).

Ankerite vein in 1257 drift showing boudinage structure with quartz ladder veins, tourmaline and sulphide mineralization.

STOP 2: 1257 Drift

Easterly extension of #1 South Ankerite shows banded alteration zone surrounding vein.

STOP 3: 1202 # 4 Drift

Volcanic - Sedimentary Interface (Greenstone Nose)

Contact with spherulitic lava and fragmental rock (conglomerate) with a matrix of "flowy" greenstone, porphyry and some sulphide clasts.

- Fragmental rocks grade to broken and fractured slate beds.

- Minor fault showing Drag Folding.

STOP 4: Timiskaming-like Metasedimentary Rocks

- Folded contact between conglomerate and Greywacke

- Graded bedding showing tops to the east.

STOP 5: 1222 Drift

- Alteration Zone "Carbonate Rock"

- Brownish coloured crystalline carbonate with dark grey ankerite streaks.

STOP 6: 1222 Footwall (F.W.) Drift - "Diabase Dike"

- Matachewan quartz diabase dike.

- Note chilled margins and wall rock baking.

STOP 7: 1222 Vein - Quartz Tourmaline Vein

- Note tourmaline banding with sulphides, pyrite and pyrrhotite.

- Fine gold occurs with the tourmaline banding.

- Highly Altered (H.A.) rock, rich in green fuchsite.

STOP 8: 1281 #1 X/C - Porphyry Lens in Highly Altered Zone

- Strongly sericite altered Quartz Albite porphyry.

STOP 9: 1281 Drift - Fuchsite Vein

- Fine gold occurs associated with narrow fuchsite bands along contacts of an otherwise massive and barren quartz vein.

- Note Carbonate Rock Host.

STOP 10: 1222 #8 Stope

- Cut and Fill panel mining of irregular veins in metasedimentary rocks.

Hollinger - McIntyre - Coniaurum Gold-Quartz System

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The Hollinger-McIntyre-Coniaurum (HMC) gold-quartz vein system extends from Timmins to Schumacher, Ontario, in the centre of the historic Porcupine mining camp (Fig. HOL1). The deposit was discovered in 1909 by surface prospecting on what is now the Hollinger property. Subsequent exploration along strike, and down plunge, led to the discovery and development of the McIntyre and Coniaurum Mines. Collective mine production totalled almost 122 million tonnes of ore, yielding 1055 kilograms (34 million ounces) of gold between 1910 and 1989, when underground operations at the McIntyre Mine were suspended. In addition, the McIntyre copper orebody, hosted by the Pearl Lake porphyry intrusion, yielded 10 million tonnes, grading 0.62 percent Cu. The properties are now owned by Giant Yellowknife Mines Limited, with property exploration programs conducted by Pamorex Minerals Incorporated, the exploration arm of the Pamour Group of Companies.

8.2.1. Regional Geological Setting

The Porcupine Mining District is located near the western edge of the Archean Abitibi Greenstone Belt, within the Tisdale assemblage (Section 4.5). Historical descriptions of the stratigraphy in the Timmins area referred to two metavolcanic assemblages of rock: the older Deloro "group" and younger Tisdale "group" (Dunbar 1948; Ferguson et al. 1968; Pyke 1982). Each "group" represents a suite of komatiitic, tholeiitic, and calc-alkalic metavolcanic rocks. In this section, to facilitate comparison with literature descriptions, the historical nomenclature is used.

"Tisdale Group" metavolcanic rocks, hosting most of the gold in the Timmins area, occur north of the Destor-Porcupine Fault, the major structural element in the Porcupine area. The spatial association between the Destor-Porcupine Fault and gold deposits has been well documented (Pyke 1982). The HMC is located on the north limb of the Porcupine Syncline, a major east-plunging basinal structure north of the Destor-Porcupine Fault. The significance of the Porcupine Syncline will be discussed later.

8.2.2. Detailed Geology

In the mine area, rocks of the Northern, Central, Vipond and Gold Centre "formations" are exposed (Fig. HOL1 and HOL2).

8.2.2.1. Northern "Formation"

Rocks of the Northern "formation" are exposed in the Hollinger and McIntyre Mine sequences, but are absent at the Coniaurum Mine. This sequence reaches an exposed thickness of 260 metres at Hollinger, comprising intercalated massive, pillowed, and locally amygdaloidal basalt flows. The uppermost part of the "formation", known as the "63-flow" (Fig. HOL2), is marked by the conspicuous development of flow-top, pillow breccias and interflow carbonaceous sediments.

8.2.2.2. Central "Formation"

The Central "formation", best exposed on the Coniaurum and northeast McIntyre properties, reaches 915 metres in thickness and is dominated by intimately interlayered massive and amygdaloidal pillowed basalts and thick sequences of flow breccia. The latter are confined to the western part of the McIntyre property, near the Pearl Lake Porphyry intrusion. Both massive and pillowed units are pale buff-green and mildly carbonatized. Pillows are generally bun-shaped and small (usually < one metre), with narrow chloritic, amygdule-rimmed selvages. Detailed mapping and core logging by staff

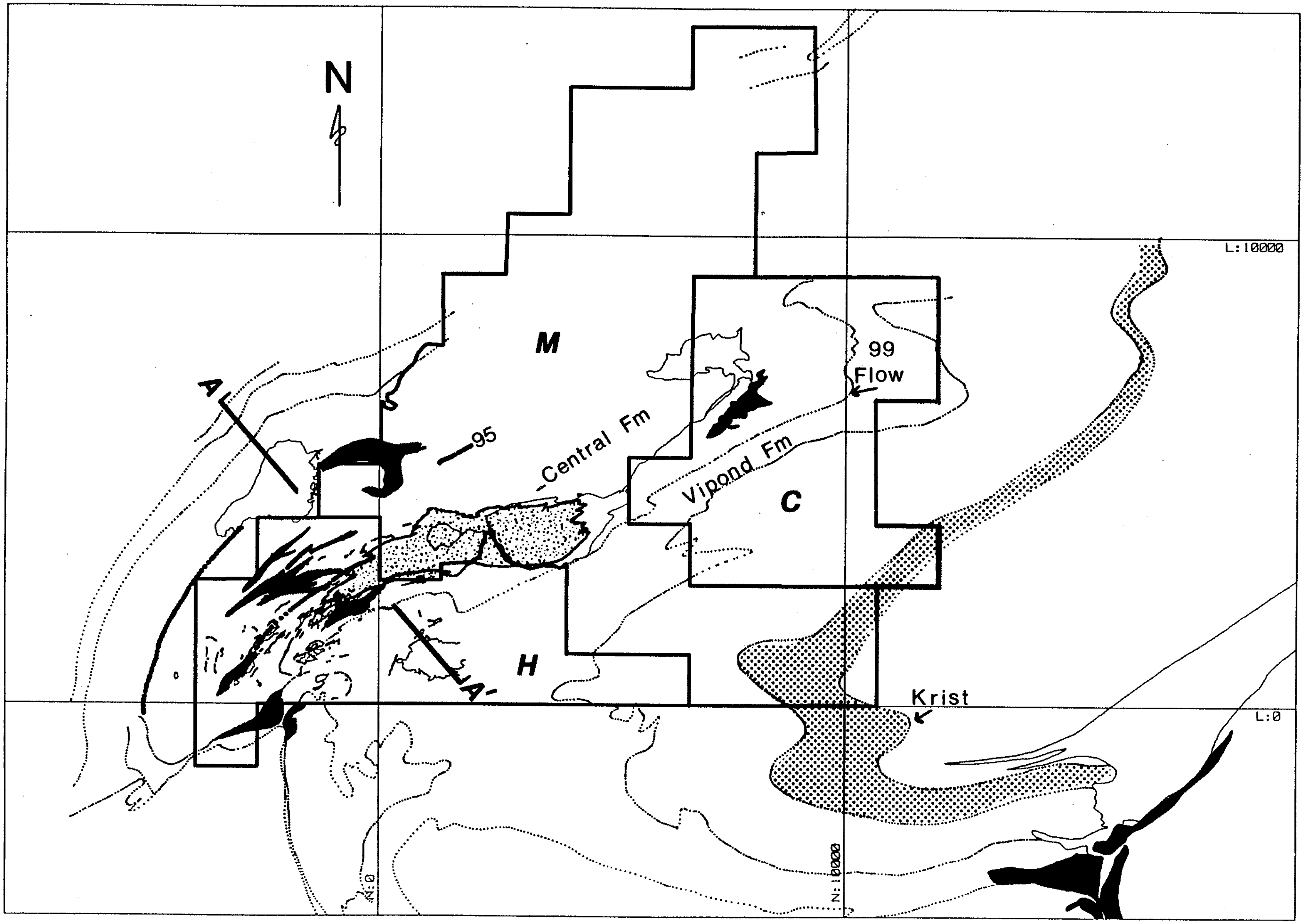

Figure HOL1: General geology of the Hollinger-McIntyre-Coniaurum area (from Ferguson et al., 1968). Pearl Lake porphyry stippled, other porphyries black; Krist fragmental at top of Tisdale "formation" is dotted. Abbreviations as follows: H-Hollinger; M-McIntyre; C-Coniaurum. Section 'A-A' refers to section of figure HOL6. Grid lines are at 3048 metre (10,000 feet) intervals.

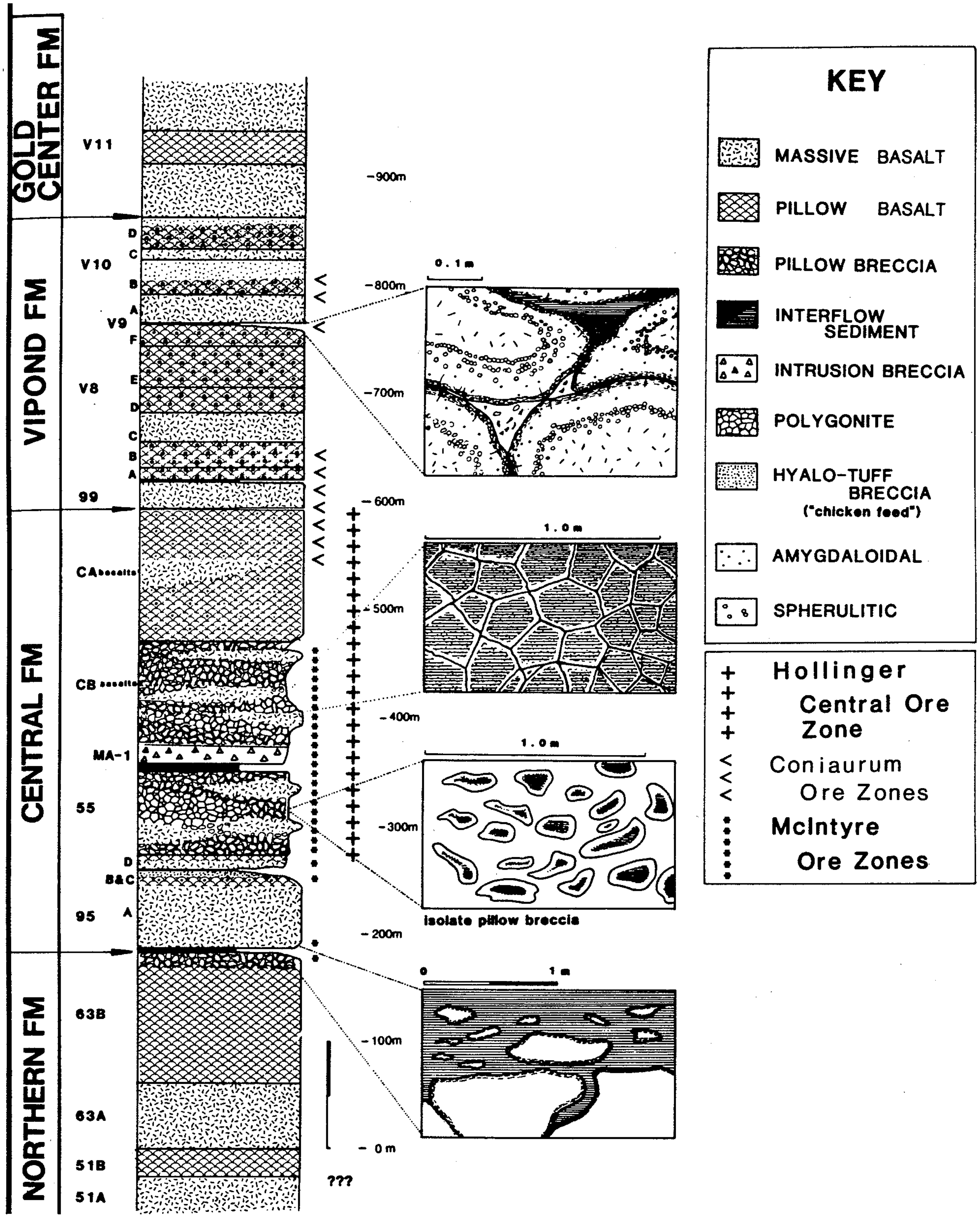

Figure HOL2: Stratigraphic column of the Hollinger-McIntyre-Coniaurum area (from Mason and Melnik 1986).

geologists have demonstrated that specific correlation of flows within the Central and Vipond "formations" is not possible, due to the rapid lateral variations in volcanic facies.

The transition from Northern to Central "formations" is marked by the presence of a thick, massive, locally hyaloclastic unit ("95-flow"), which overlies flow top breccias and interflow sediments of the Northern "formation". Excellent exposures of massive and amygdaloidal flows within the Central "formation", occur in the Coniaurum Lake area ("89-vein" zone) and in the Bishop Shaft area of the Coniaurum mine ("53-vein" zone).

8.2.2.3. Vipond "Formation"

The transition from Central to Vipond "formation" metavolcanic rocks is the most consistent and reliable transition in this part of the Timmins camp. The base of the Vipond "formation" is marked by the "99-flow", which Pyke (1982, p.87) called the "first easily recognizable iron-rich, tholeiitic basalt in the lower part of the Tisdale Group". Observations along the HMC trend suggest that the "99-flow" is not a single unique flow, but is a sequence of massive flows, collectively up to 30 metres in thickness, which separates rocks of the Central and Vipond "formations". The least altered "99-flow" is a medium grained, dark green, chloritic, leucoxene-rich, massive basalt unit, although few exposures of such least altered rock exist. More commonly, the "99-flow" is intensely carbonatized and locally sericitized, and is tan to light green in colour. It is rarely exposed on surface, but is consistently intersected by diamond drilling. Variable deformation and alteration intensities, as well as abundant gold-quartz veining at the Coniaurum Mine, have produced a unit which is visually diverse over short distances. Discontinuous lenses of carbonaceous argillite locally bound both contacts of the "99-flow" unit. In the "10-vein" area at Coniaurum, up to 4.5 metres of semi-massive pyrite mineralization forms the footwall to the "99-flow" unit.

Stratigraphically above the "99-flow" unit are 150 metres of intercalated, massive and variolitic pillowed basalts, collectively known as the "V8-unit". This is an important regional marker sequence of historical significance. Where unmineralized, pillowed basalt sequences are dark green and chloritic. White-coloured, elongate varioles, ranging from one to 10 millimetres in diameter, comprise up to 30 percent of the flow. Pillows are mattress-shaped, reach up to 2.5 metres in length, and have broad, intensely chloritized selvages with abundant interstitial debris. Variole distribution is complex within a given exposure. Coalescing varioles may occupy the core or rim, or may be concentrically distributed throughout a pillow. These features may reflect flow rheology and drainage patterns within individual lava tubes. Outcrops of the "V8-unit" are present throughout the camp, but the sequence is best exposed on the Coniaurum and Hollinger properties.

Near the top of the "V8-unit", variolitic pillow selvages display increasing degrees of hyaloclastic brecciation, marking a gradational transition to "V10-type" hyaloclastite sequences. The top of the "V8-unit" is defined by two parallel carbonaceous argillites, separated by 7 to 10 metres, which are known as the "V9-unit". These carbonaceous units, 0.3 to 3 metres in thickness, are remarkably continuous in the HMC, and are used locally as reliable marker units. Local high grade, but volumetrically insignificant, gold-quartz mineralization has been exploited from such units, where they were affected by small-scale folding.

The "V10-unit", consisting of alternating massive basalts and variolitic hyaloclastites, occurs stratigraphically above the "V9-unit". This unit is interpreted as completely disrupted equivalents of "V8-unit" flows. Variolitic hyaloclastites consist of coarse, angular, 2 to 10 millimetre shards, which sit in a dark green chloritic matrix. Historically, this is referred to as "chicken-feed" texture. The maximum recorded thickness of the "V10-unit" is approximately 150 metres.

Although several units within the Vipond "formation" have been used as local and regional marker units (e.g., massive "99-unit"; variolitic "V8-unit"; hyaloclastite "V10B-unit"), detailed mapping and core logging by Pamorex staff suggests that broad stratigraphic correlations at the unit scale are possible, but specific correlations of individual flows within the Vipond sequence are not possible. Rapid lateral and vertical facies changes in these metavolcanic sequences make correlation of similar-looking flows contentious, and may have contributed to unwarranted previous interpretations of structural complexities in this part of the camp.

8.2.2.4. Gold Centre "Formation"

The Gold Centre "formation" is a poorly documented sequence, the thickness of which exceeds 150 metres. It is best exposed on the Coniaurum property, along the power line north of Highway 101, and it has been extensively intersected by diamond drilling by Pamorex in the mine site exploration programs.

The Gold Centre "formation" is dominated by very coarse-grained, dark green, chloritic, massive flows. Unique to this sequence are abundant and coarse-grained (1 to 3 millimetres), trellis-textured leucoxene and brilliant, fracture-controlled epidote. Though not historically noted as a gold host in the HMC, economic grade mineralization has been encountered in the Gold Centre sequence by the staff of Pamorex.

8.2.2.5. Intrusive Rocks

In the HMC, the volcano-sedimentary sequence is intruded by a number of felsic, porphyritic stocks, including the Pearl Lake, Coniaurum and Gillies Lake Porphyries. Underground observations suggest that these bodies coalesce with and are apophyses off a larger intrusion at depth. Chemically, the porphyries show similarities to sodic, high-alumina trondhjemites. Most porphyries (notably the Pearl Lake, Acme, Millerton and Coniaurum) have been subjected to intense deformation and alteration, and are best described as quartz-sericite schists. Associated with porphyry intrusions are small amounts of heterolithic intrusion breccias, well exposed on both the Hollinger and Coniaurum properties. These breccias are found both as discordant, irregular, narrow dikes and as marginal zones at porphyry contacts. Minor albitite dikes are also present in the Hollinger-McIntyre mine sequence, where they cut, and are therefore later than, the porphyry intrusion, but earlier than gold mineralization (cf. Mason and Melnik 1986). One albitite dike has a crystallization age of 2673 Ma (Marmont and Corfu 1989).

8.2.2.2. Geochemistry

Geochemical investigations of host metavolcanic rocks has concentrated on the Central and Vipond "formations". Jensen Cation plots (Jensen 1976) and representative REE plots are given in figure HOL3 and HOL4. Metavolcanic rocks plot within the field of iron-rich tholeiitic basalt. Most REE plots are flat to mildly sloping. A number of trace elements (especially vanadium) and immobile element ratios have been found useful in geochemical discrimination; however, details are beyond the scope of this paper. A representative summary of analyses is given in Table HOL1.

8.2.2.3. Structure

Rocks of the HMC strike roughly 070° and dip steeply to the north or south. Facing directions are generally south, although reversals related to the Hollinger and Coniaurum Anticlines have been identified. Regional scale structures of the Timmins camp are discussed in Section 4.5 and are mentioned only briefly in this section. The extent and significance of many of these structures remain contentious issues. For example, Mason and Melnik (1986) suggest volcanic stratigraphy at HMC forms a complete periclinal dome, whereas observations by the staff of Pamorex Minerals Incorporated and others (D. Brisbin, Senior Mine Geologist, Falconbridge Limited, Kidd Creek Mine, personal communication, 1990) suggest a less complete closure of the Coniaurum Anticline, such that stratigraphy continues on an eastward trend toward the Burrows-Benedict Fault.

Large scale fold structures, such as the Porcupine Syncline and Coniaurum Anticline have been shown by Roberts (1981) to be "early" folds bearing no associated penetrative fabrics, and are attributed to synvolcanic basin development. The dominant regional fabrics comprise a well-developed foliation and lineation (S1 and L1 of Roberts 1981), which transect the axial trace of the Porcupine Syncline and which are present in all rock types except late diabase dikes (Fig. HOL5). In the HMC, foliations are near-vertical and strike 070° to 080°, locally subparallel to stratigraphy. Lineations, defined primarily by pillow, amygdule and variole elongations, and plunge 55° east. This regional plunge coincides with the rake of most ore shoots and felsic porphyritic stocks. These fabrics are the most characteristic structural elements of the central Porcupine camp and can be observed in most outcrops.

Locally, in the corridor defined by the HMC, well-developed, discontinuous, shear zones are present in all rock types, except diabase. These shears are host to most gold mineralization.

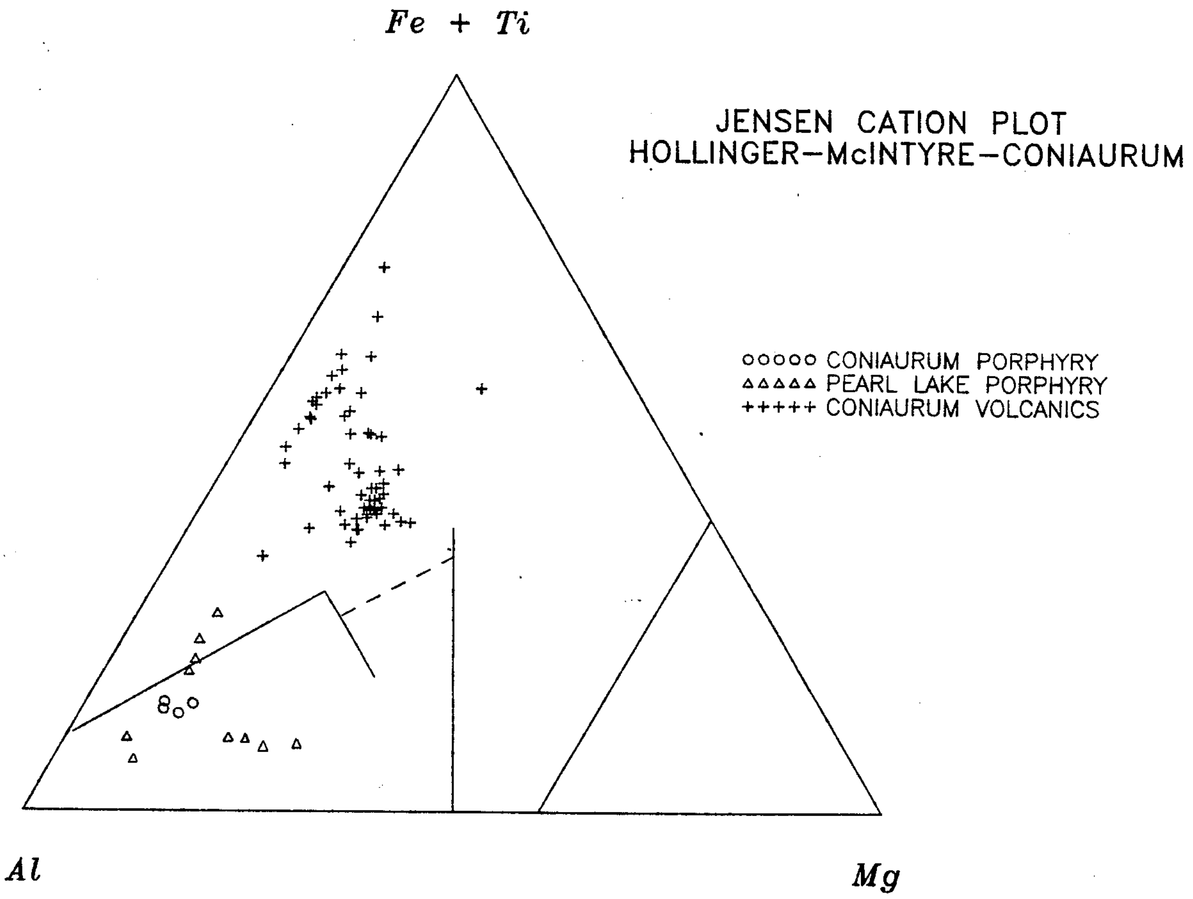

Figure HOL3: Representative chemical classifications of rocks from the Hollinger-McIntyre-Coniaurum area, using the Al-Fe+Ti-Mg cation plot of Jensen (1976).

8.2.3. Mineralization

Gold-quartz mineralization in the HMC occurs in two principal and three subordinate forms: 1) shear-hosted, vertical veins which cut metavolcanic and metasedimentary rocks; 2) flat veins related to (1); 3) metavolcanic and sediment-hosted, fold-related, "hook-veins"; 4) porphyry-hosted, discontinuous veins; and 5) stockwork gold-quartz stringers which cut heterolithic intrusion breccias.

8.2.3.1. Shear-hosted Vertical Veins

Most gold mineralization in the HMC occurs in vertically dipping veins which are hosted within intensely deformed and altered metavolcanic and metasedimentary rocks. Veining is particularly concentrated at the west end of the Pearl Lake porphyry, on the Hollinger property, in an area termed the "Central Ore Zone" (Fig. HOL6).

Intensely deformed quartz (+/- albite-tourmaline-sericite) veins vary in width from centimetres to swarms reaching several metres in width. Gold occurs as the native element and in fine-grained, xenoblastic pyrite, concentrated along sericitic wall rock selvages. Pyrite is the dominant sulphide, locally comprising 10 percent of the rock. Other sulphides, including pyrrhotite, chalcopyrite, sphalerite and arsenopyrite, are rarely noted.

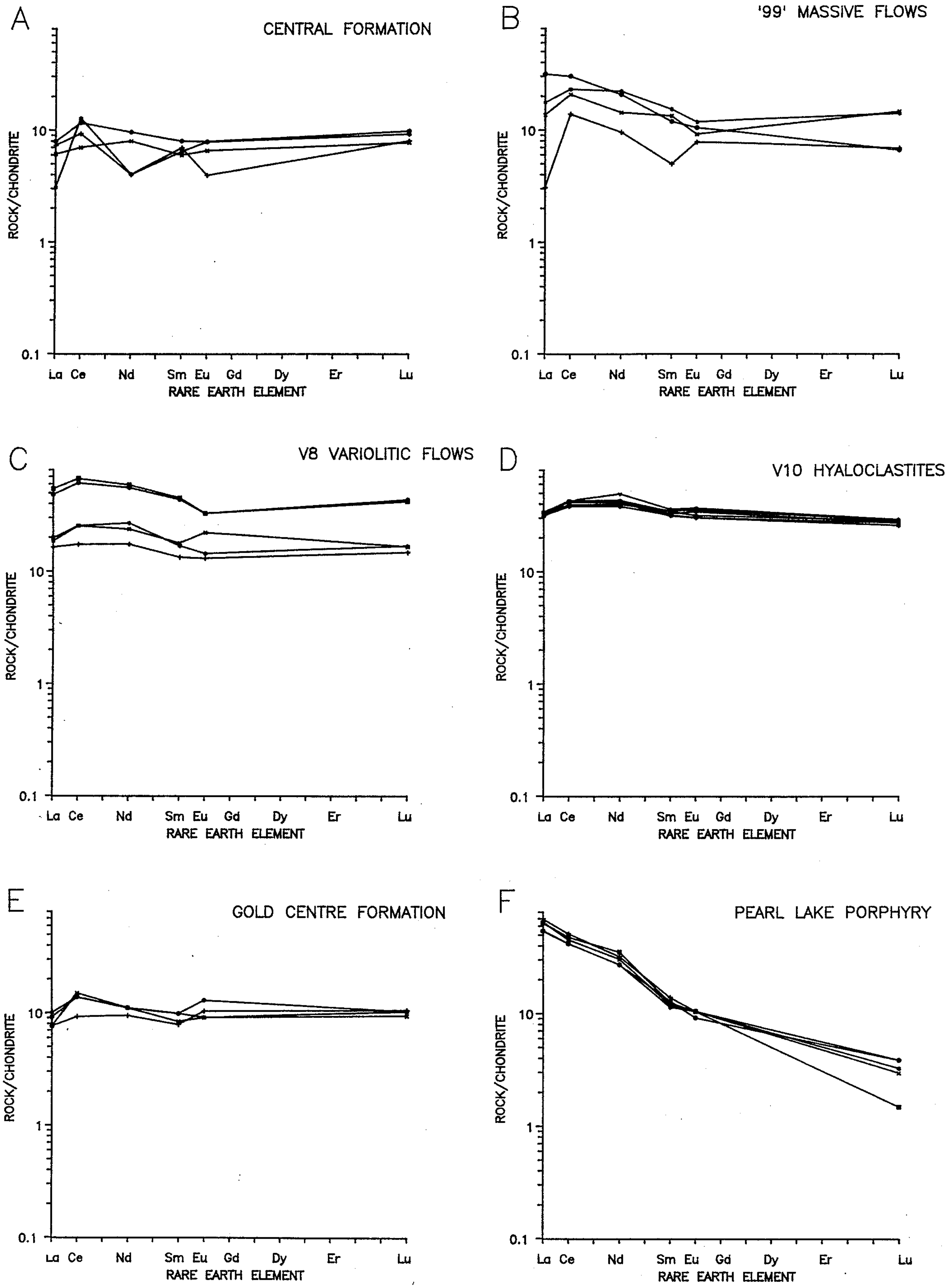

Figure HOL4: Representative rare earth plots for rocks from the Hollinger-McIntyre-Coniaurum area: a) Central "formation" metavolcanic rocks; b) "99" massive mafic unit; c) Vipond "formation", V8-variolitic flows; d) Vipond "formation" V10-hyaloclastites; e) Gold Centre "formation" massive flows; f) Pearl Lake porphyry.

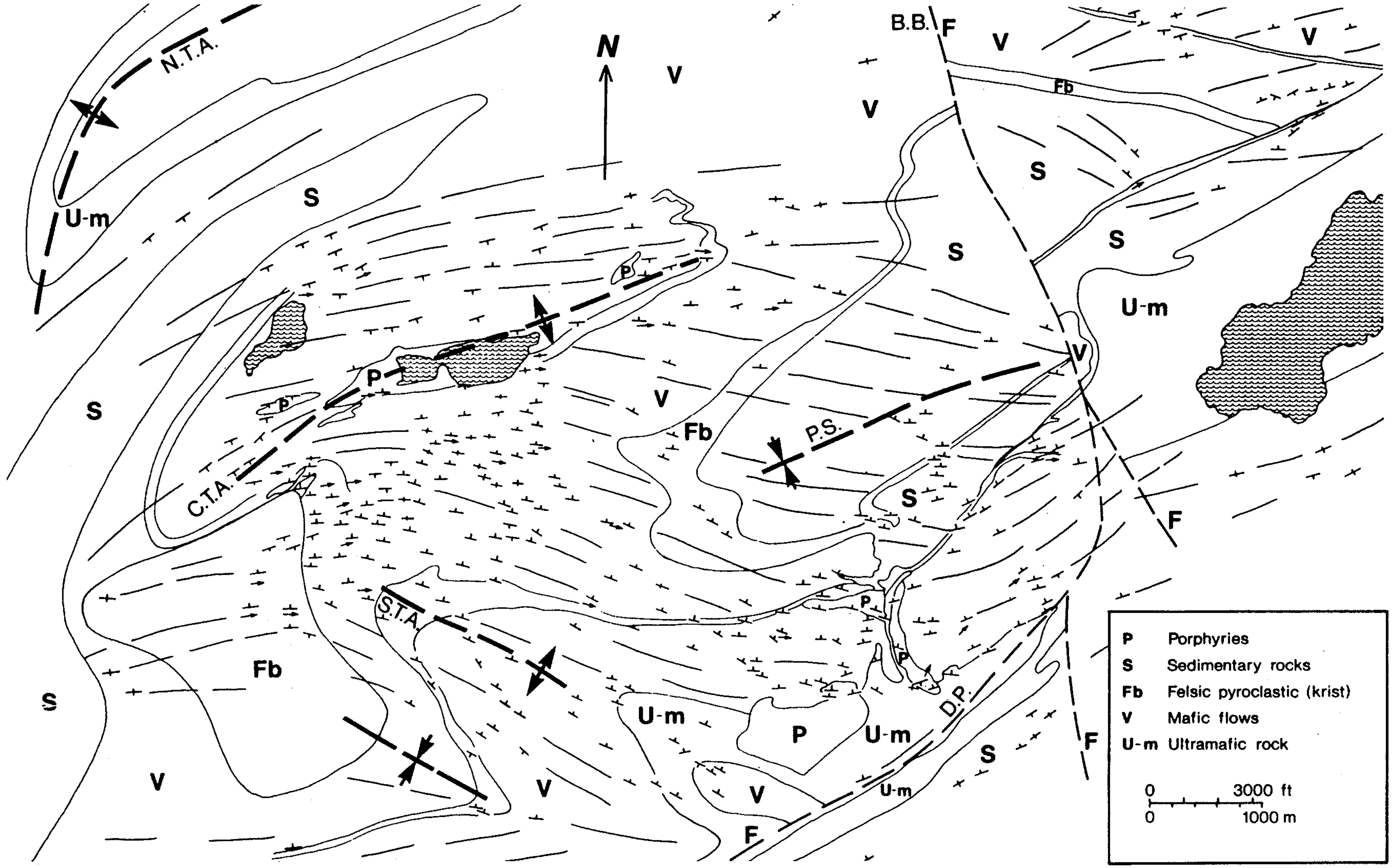

Figure HOL5: Sythesis of major structures and attitudes of S_1 and L_1 in the Timmins area. N.

TABLE HOLI

AVERAGE TRACE ELEMENT GEOCHEMISTRY OF VOLCANIC AND INTRUSIVE ROCKS IN THE HOLLINGER-McINTYRE-CONIAURUM AREA

	GOLD CENTRE FORMATION	V10	V8	99	CENTRAL FORMATION	PEARL LAKE PORPHYRY
V ppm (range)	350-460	60	290-330	180-260	220-310	60-80
V ppm (average)	427	60	252	227	268	68
Cr ppm	80	51	68	120	126	67
Ni ppm	100	11	44	46	59	16
TiO2 %	1.21	1.51	1.13	1.24	0.67	0.40
Zr ppm	34	192	90	72	21	96
Rb ppm	15	20	35	55	32	85
Sr ppm	24	65	64	75	59	152
Nb ppm	16	22	17	11	8	11
Y ppm	11	66	37	24	12	10
Ba ppm	79	73	204	230	240	405
Total REE * ppm	61-91	82-116	41-48	45-53	7-22	74-91
(La/Lu)n	0.7-1.5	1.5-4.5	2.0-12.3	0.9-4.9	0.7-0.9	14.2-22.2
(average)	1.3	3.8	5.9	2.3	0.8	17.8

* based on 6 REE

Quartz veins generally strike 070° and dip steeply to the north or south, coincident with regional fabrics. These veins usually occupy the cores of variably developed shears. Locally, veins can be shown to follow preferred hosts, such as pillow breccias (e.g., "53-vein"), flow contacts ("11-" and "12-veins" at Coniaurum) or interflow metasedimentary units ("20-"and "24-veins" at McIntyre). At McIntyre, for example, 46 percent of gold production came from four vein structures located along flow contacts.

8.2.3.2. Flat Veins Related to Vertical Veins

Flat veins, usually related to a parental, vertical structure, are common on all properties. Similar to vertical veins in mineralogy, the flat veins range from less than two centimetres to several tens of centimetres in width, and represent the filling of extensional fractures (Hall 1985). Many flat veins at Hollinger were prolific producers. For example, the "97/154-flat vein" complex produced in excess of 408,000 tonnes grading 7.7 g/tonne Au (Hall 1985).

8.2.3.3. Volcanic and Sediment-hosted, Fold-related "Hook-Veins"

A number of "hook veins" occur at both Hollinger and Coniaurum. These are narrow vein structures localized at closures of small scale folds, especially within interflow metasedimentary units. McIntyre "20-" and "24-veins" and Coniaurum "2-" and "5-hook-veins" have all been minor gold producers.

8.2.3.4. Porphyry-hosted, Discontinuous Veins

Gold mineralization in the Pearl Lake porphyry consists of erratic, discontinuous vein zones located south of the copper orebody. At McIntyre, "10-vein", located within the porphyry, produced 790,000 tonnes grading 10.8 g/tonne. Quartz veins are abundant in the Pearl Lake porphyry. These veins range from 0.3 to 2.5 metres in width, occur in the core of intensely bleached and sericitized pyritic alteration zones, and tend to be erratic and of low gold grade. It is suggested that the ductile deformation of the porphyry has inhibited vein development and disrupted existing veins, unlike the more brittle, bounding metavolcanic rocks. Minor gold mineralization has also been encountered within the Coniaurum Porphyry.

8.2.3.5. Stockwork Gold-quartz Stringers in Heterolithic Intrusion Breccias.

Minor, quartz-stockwork, stringer zones occur in sericitic, heterolithic breccias at or near porphyry contacts. Of minor importance, and limited extent, stockwork zones likely played host to part of the "12-", "72-" and "53S-vein" systems at Coniaurum.

8.2.4. Rock Alteration

Vein-associated hydrothermal wall rock alteration in the HMC has been well documented. Background greenschist assemblages in most metavolcanic rocks consists of pervasive epidote-calcite-chlorite, most likely representing early seafloor processes, analogous to those described by Thompson (1984) and Mottl (1984). This corresponds to the "Least Altered Facies" of Piroshco and Hodgson (1988).

Vein-associated alteration zones generally consist of three zones, similar to those described by Piroshco and Hodgson (1988): 1) an outer zone of chlorite and low-iron dolomite; 2) a central zone of high-iron dolomite to ankerite; and 3) an inner zone of abundant sericite and ankerite. These alteration zones may be greater than 130 metres in width, and are generally gradational in nature. At the "89-vein" zone alteration fronts are sharply defined and well exposed on surface.

Chlorite-zone rocks are extensively exposed on surface and host barren quartz veins. Inner ankeritic and sericitic zones, corresponding to the "Ankerite Facies" of Piroshco and Hodgson (1988), host most of the mineralized vein systems and are usually coextensive with shear zones. Pyrite is a common constituent of the inner alteration facies which is defined by intense, locally porphyroblastic, ferroan dolomite alteration. Intense sericite alteration is usually restricted to vein margins.

8.2.5. Temporal Constraints

The relative timing of alteration, deformation and gold mineralization in the Porcupine camp has been a source of contention for many years. Table HOL2 presents a schematic depiction of the geological evolution of the HMC as interpreted by the staff of Pamorex Minerals Incorporated. At Timmins, early folding related to synvolcanic basin development (Roberts 1981) produced large-scale, synformal-antiformal pairs with no associated fabrics. Continued rotation of Tisdale "group" metavolcanic rocks and

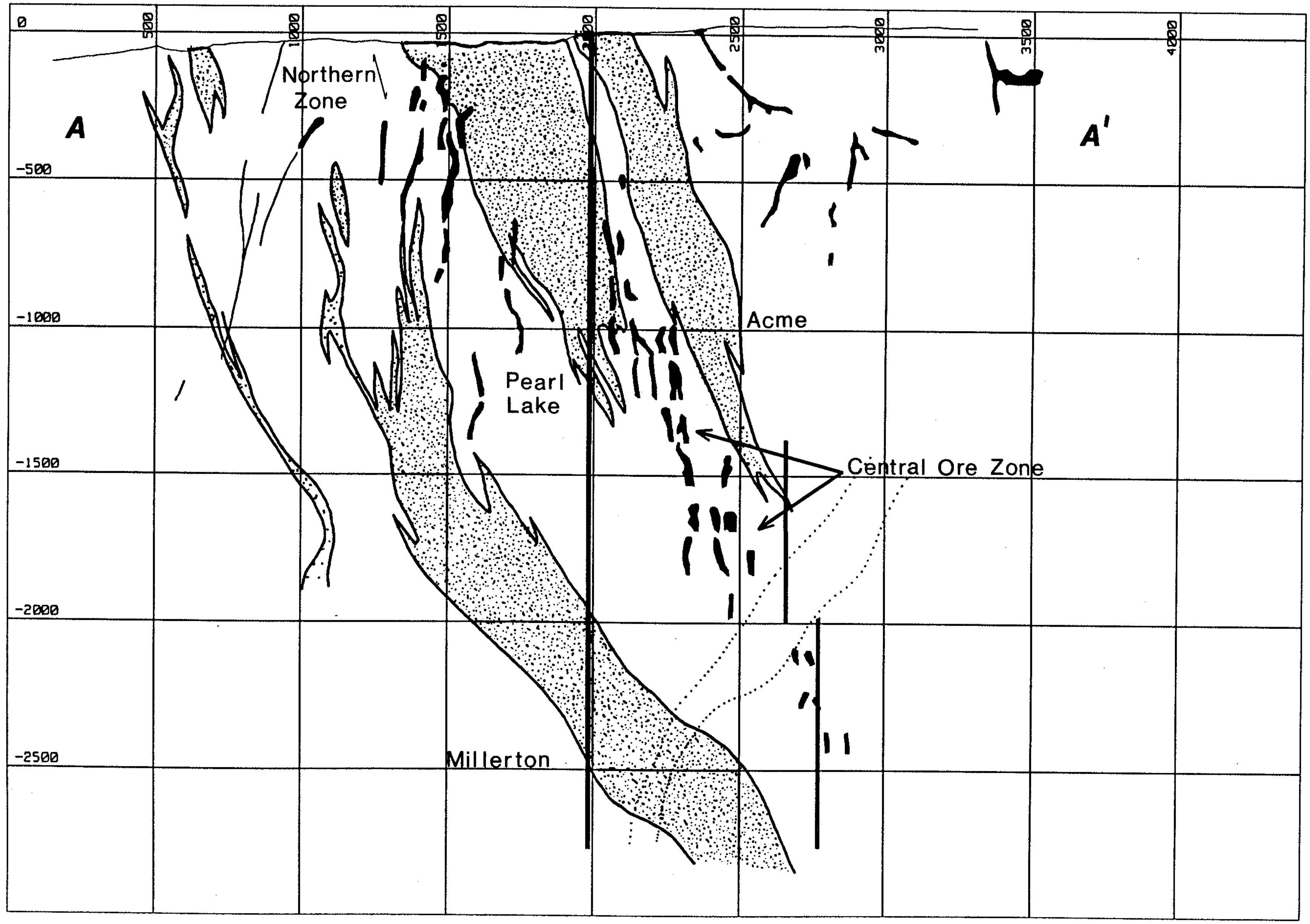

Figure HOL6: Section 'A-A', looking northeast through the Central ORe Zone at Hollinger, highlighting the density and en echelon style of veining. Porphyritic stocks shown in stippled pattern. Grid lines are at 152 metre (500 feet) intervals.

TABLE
HOL2
SEQUENCE OF EVENTS AT HOLLINGER-McINTYRE-CONIAURUM

TISDALE VOLCANISM
2700 M.Y.

FOLDING: PORCUPINE SYNCLINE,
CONIAURUM ANTICLINE etc.

FAULTING

TIMISKAMING SEDIMENTATION

CONTINUED FOLDING, FAULTING

INTRUSION OF PEARL LAKE
AND OTHER PORPHYRIES (2688 M.Y.), BRECCIA DYKES
AND ALBITITE DYKES

ONSET OF REGIONAL DEFORMATION; DEVELOPMENT OF
PLANAR AND LINEAR FABRICS:
CONTINUES THROUGH

HYDROTHERMAL ALTERATION, INITIATION OF SHEAR ZONES,
VEIN FORMATION AND MINERALIZATION

FAULTING; FLAT THRUST FAULTING AT HOLLINGER,
McINTYRE AND CONIAURUM

DIABASE, NNW FAULTING, REACTIVATION
OF EW FAULTS

movement along east-striking faults, predated initiation of Timiskaming sedimentation.

Crosscutting relationships, particularly with the Coniaurum Porphyry, indicate felsic porphyritic stocks were emplaced into steeply dipping and folded stratigraphy. The coincidence of regional planar and linear fabrics with the orientation of shears, veins, ore shoots and the plunge of the porphyries suggests that alteration and mineralization were coincident with the main stages of regional deformation. This interpretation differs significantly from that of Mason (1986) and Mason and Melnik (1986). The rake of vein systems, intensity of deformation and internal vein textures reflect periodic fracture opening under high fluid pressures in a north-directed, compressional stress field (e.g., Sibson 1985; Sibson et al. 1975, 1988).

8.2.6. Tour Guide

Stop 1 "89-Veins", Coniaurum Lake Area

The "89-veins" lie on the southwest shore of Coniaurum Lake, 1.6 kilometres northeast of McIntyre 11 shaft (Fig. HOL7, 8). Although some trenching dating back to the 1940's had been conducted on this zone, the area remained relatively unknown until 1989, when an extensive drilling, stripping and mapping program was conducted.

The Coniaurum Lake area is underlain by pillowed and coarse-grained, massive basalt of the Central "formation", which have a 070° strike and a steep, southerly dip. Facing directions from local pillow exposures are to the south. The contact between amygdaloidal pillow lavas (APL) and massive flows is exposed in the stripped area. All rocks in the area possess a characteristic regional foliation and lineation, as previously discussed (Section 8.2.2.3.).

Least altered rocks in the "89-vein" area are pale green, chlorite-calcite spilites typical of the Central "formation". Overprinting background alteration is a 60 metre wide zone of intense dolomite alteration. Alteration fronts are abrupt and obvious on surface exposures, and crosscut lithological contacts. Intense dolomite-sericite alteration facies occurs at the core of the zone, coincident with well-developed, braided, anastomosing shear zones. The shears are irregular, with an overall strike of 070° to 075° and vertical dip. The general geometry of the shear system at this stop is similar to that described by Poulsen and Robert (1989; Fig. HOL9).

Mineralized quartz veins occupy the core of a number of the shear zones. Veins on surface reach a maximum width of four feet, but swarms in excess of 15 metres in width have been intersected at depth. Veins comprise strongly deformed quartz, with tourmaline-sericite-pyritohedral pyrite haloes. Angular wall rock fragmentation and vein laminae provide evidence for hydraulic brecciation and crack-seal vein growth (Melling et al. 1986; Ramsay and Huber 1983; Sibson et al. 1975). Vertical veins are accompanied by a well defined, west-dipping, extension fracture set. Both vein sets carry coarse-grained, visible gold. North- and south-dipping joint-fracture sets also occur, but they are less well developed and are not known to be mineralized. Diamond drilling has shown this target to have good lateral and vertical continuity, but erratic gold grades.

Shear zones in the area dip steeply and strike approximately 070° (Fig. HOL10A). Three joint sets are recognized (Fig. HOL10B): west-, south-, and north-dipping. The west-dipping joint set (Fig. HOL10C) contains auriferous quartz veins which are oriented approximately normal to the regional lineation (-55° plunge and 070° trend). The observed orientation of joints, quartz veins and shear zones in this area is consistent with a principal compressive stress direction (sigma 1) of 340° and a . er. (-55°), east-northeast extension direction (Fig. HOL10D). Folding of the main, vertical quartz veins in the 070° shear foliation plane suggests a dextral component of slip. Structural analysis of the "89-veins" and related shear zones indicates that north oriented (340°) compressive stress, and 55° east-plunging extension directions, resulted in the development of the steeply dipping shears and mineralized vertical and west-dipping extension veins. Most shears appear to have a dextral component of horizontal slip. It is interesting to note that the structural settings described above are found to be valid for the entire HMC (e.g., Hall 1985; Wood 1987).

8.2.7. **Stop #2** "53-" and "53S-Vein" Area

The "53-" and "53S-vein" areas are located 210

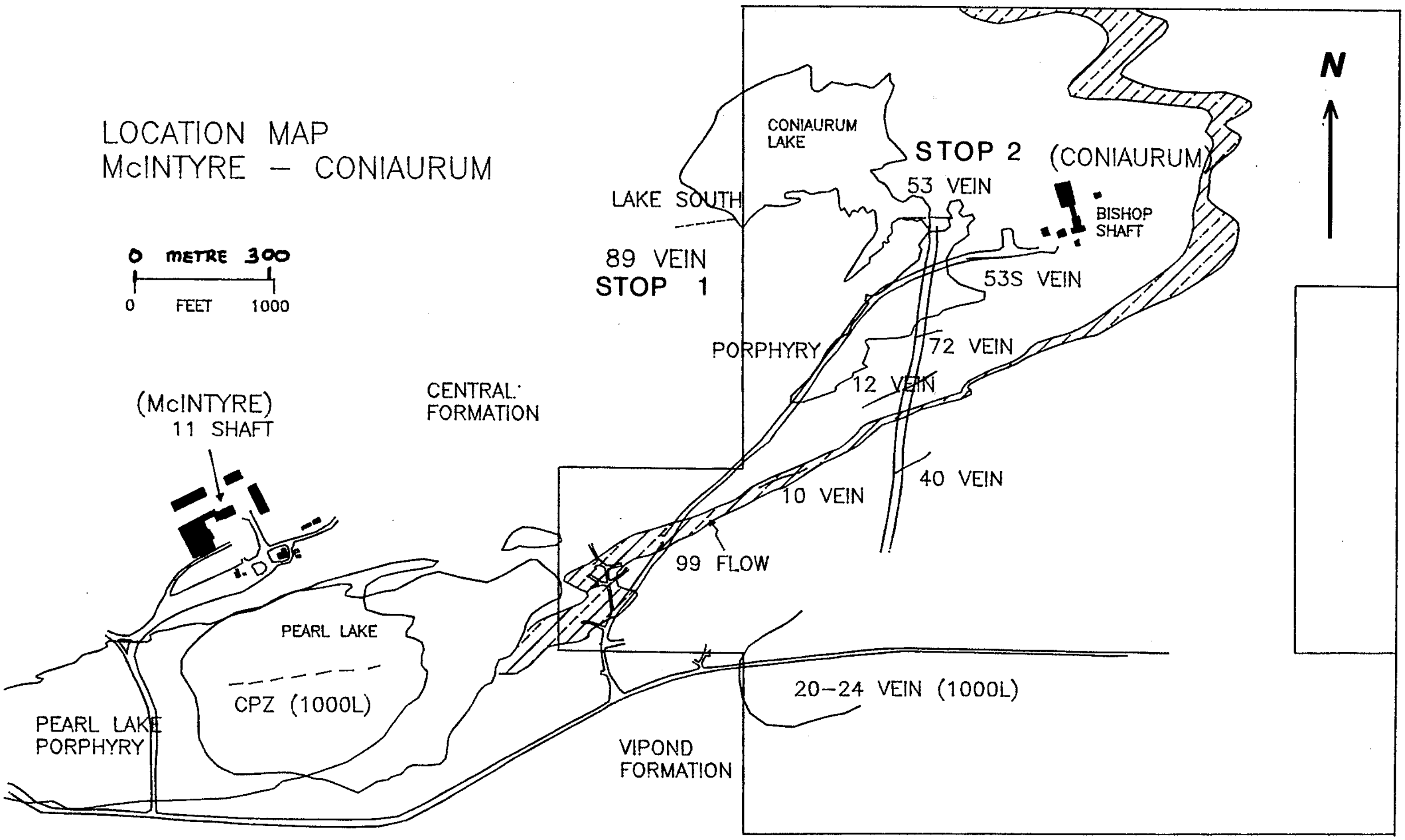

Figure HOL7: Location map for the '89-vein" and "53-" and "53S-vein" stops on the surface tour, McIntyre-Coniaurum Mine area.

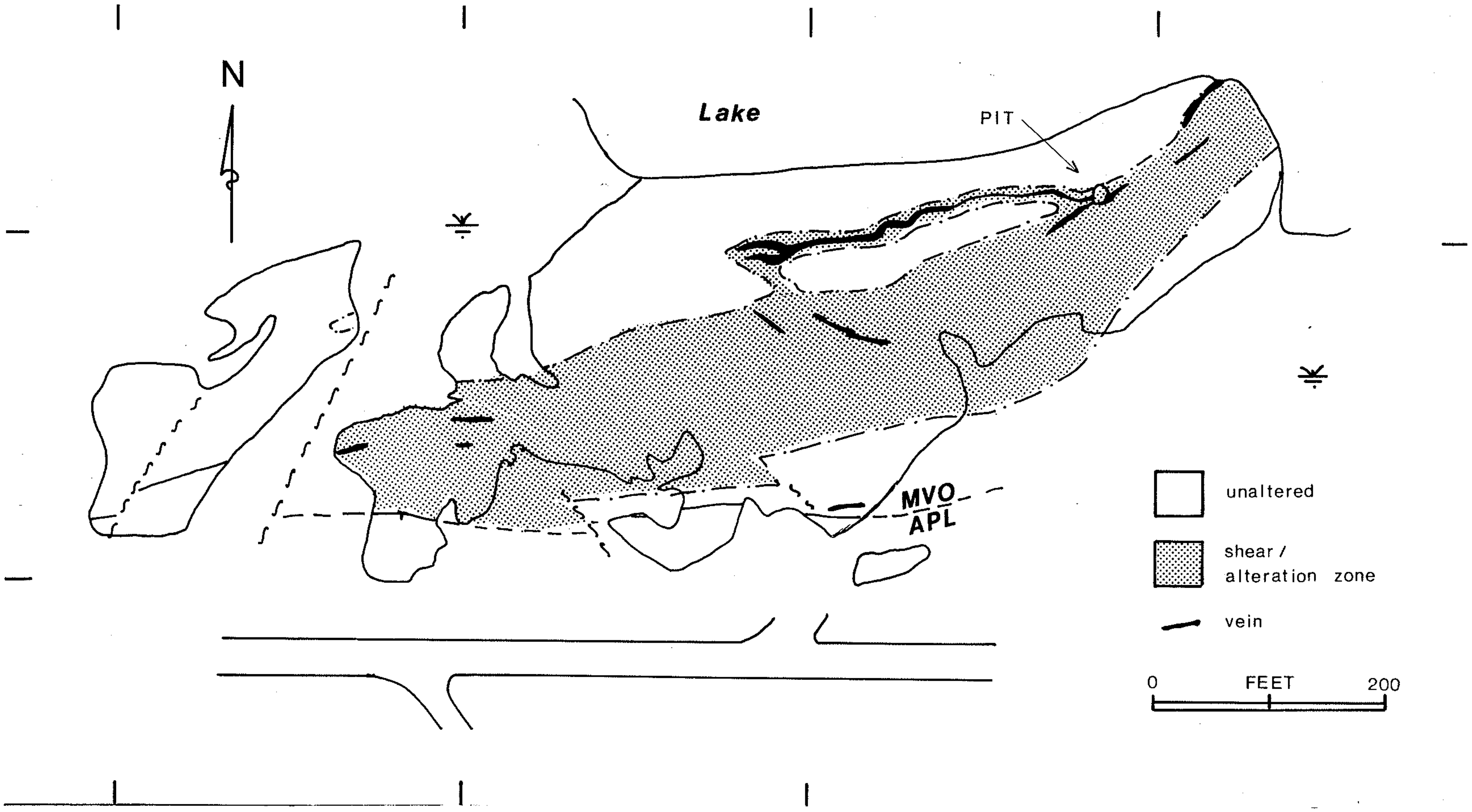

Figure HOL8: Distribution of alteration about the "89-vein", Coniaurum Lake area. Abbreviations as follows: MVO-massive mafic rocks; APL-amygdaloidal pillow lavas.

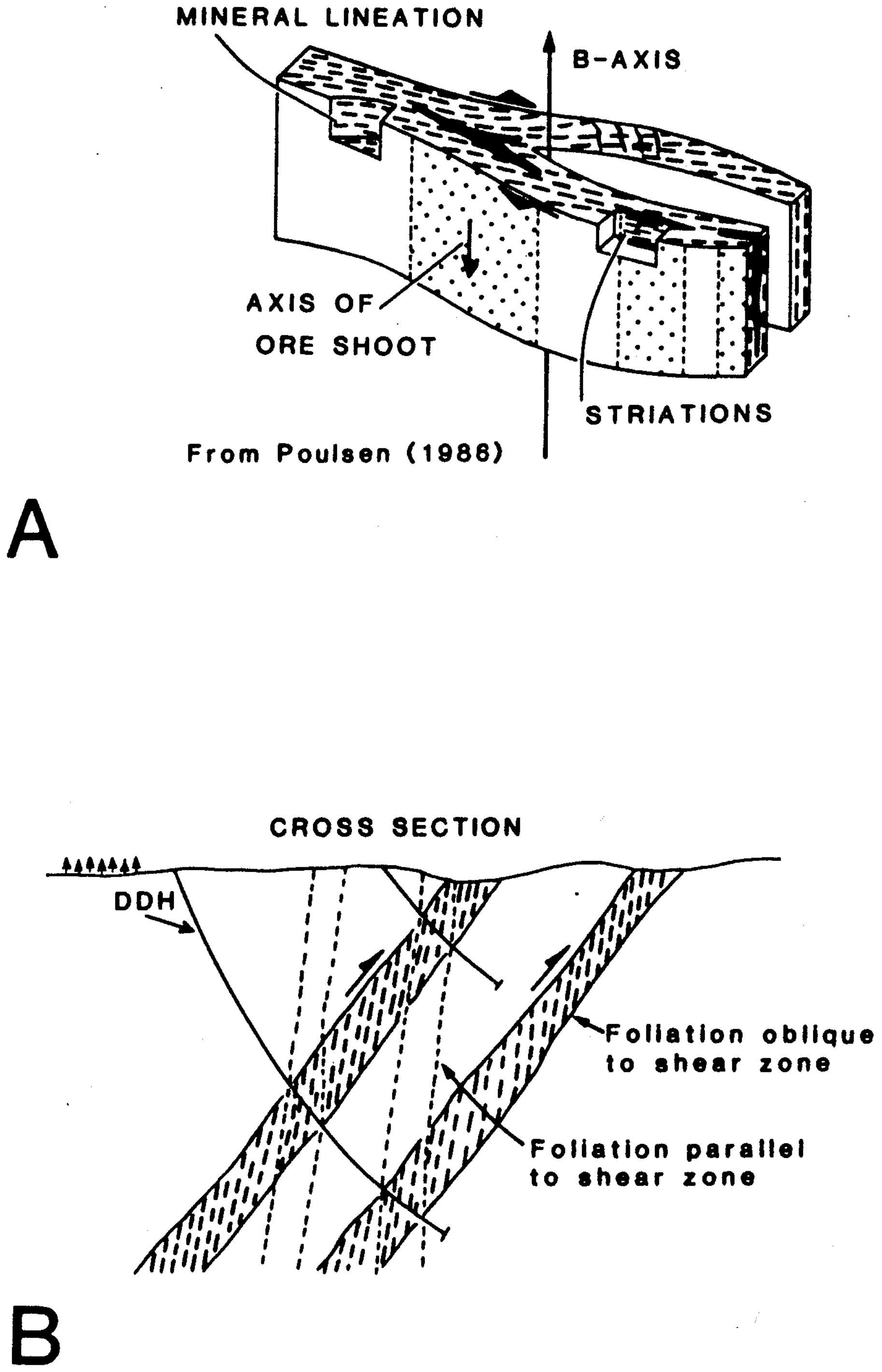

Figure HOL9: Schematic diagram of shear zone geometry as exposed at the "89-vein" zone: a) diagram illustrating structural elements including shear zone boundaries, internal fabrics and veins; b) diagram illustrating two possible shear zone orientations as interpreted from drill hole information. (From Poulsen and Robert 1989).

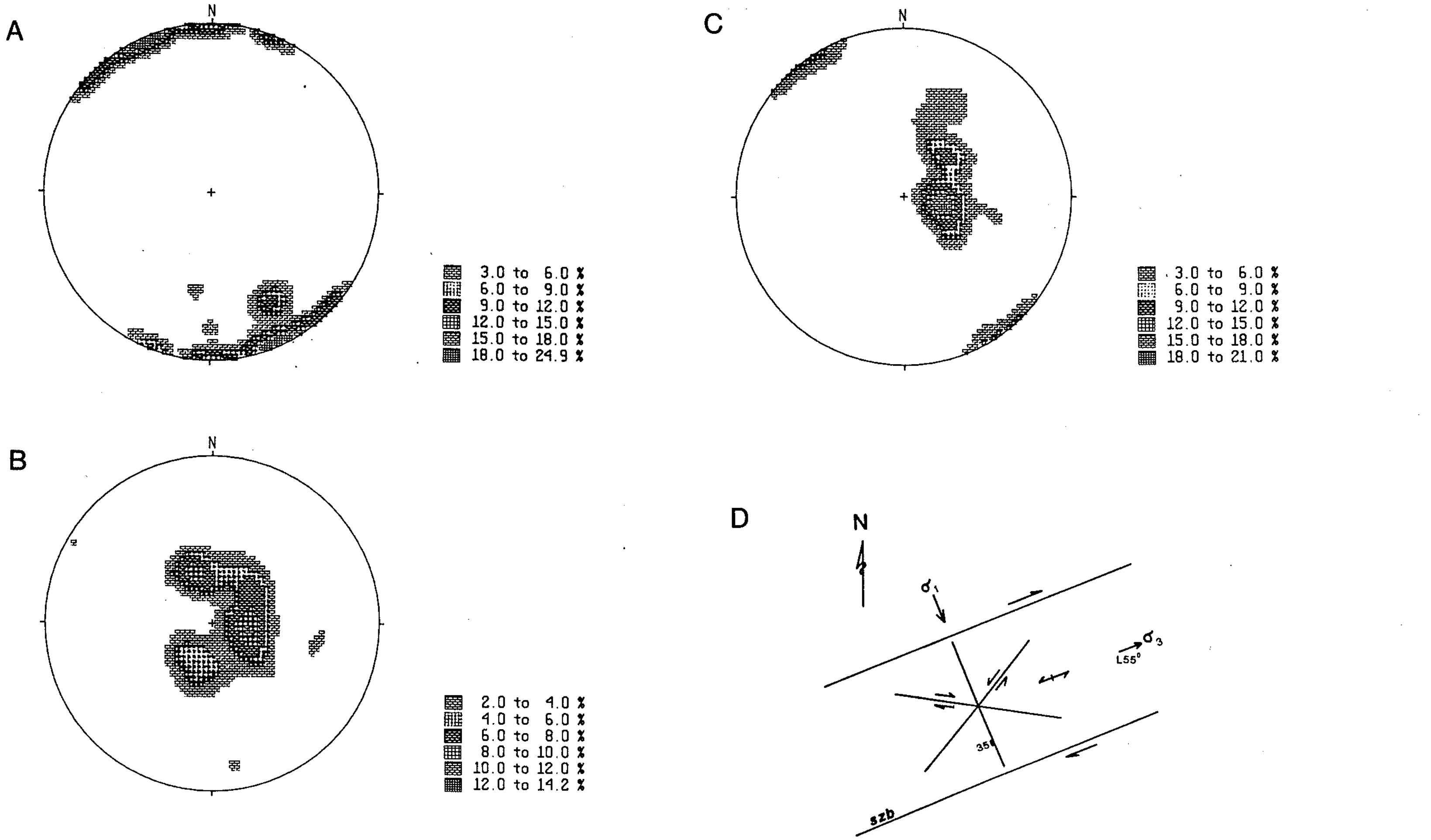

Figure HOL10: Density contoured equal area stereographic projection of structural elements from the "89-vein" zone: a) poles to shear zone boundaries; b) poles to joints; c) poles to flat or west-dipping veins; d) schematic summary of stress field (szb-shear zone boundary). See text for discussion metres west of the Bishop shaft, on the Coniaurum property (Fig. HOL7). The "53-vein", located near the shore of Coniaurum Lake, consists of irregular masses of quartz, which occupy the core of an intense dolomite alteration zone. This vein system, cut by a north-northeast-trending, east-dipping fault, follows a well defined pillow breccia unit of the Central "formation". The altered pillow breccia sequence is bound to the north by unaltered, massive flows. Diamond drilling has shown "53-vein" has a strike length of 120 metres, is open past a tested depth of 150 metres, and contains consistent economic gold grades.

The "53S-vein" zone occurs on the south side of the Carium road, 90 metres from the main "53-vein" zone. Here, a large quartz vein swarm cuts amygdaloidal pillow flows of the Central "formation", immediately east of the cuspate contact of the Coniaurum porphyry intrusion. In this area, intensely sericitized, marginal heterolithic-breccias (not exposed) are known to form a contact phase against the porphyry contact, and contain stockwork gold-quartz mineralization. This contact dips 55° east, and projects under the stripped area. Quartz veins exposed on surface occur in unaltered mafic flows above the breccia mineralization; the zone is a good example of barren veins in unaltered rock and of the contrasting style of veins between breccias and mafic flows.

Pamour # 1 Mine

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Located 20 kilometres east of the Timmins city centre, the Pamour #1 Mine has produced gold continuously since 1936 except for a two month hiatus in 1983 that resulted from a labour dispute. Total production to the end of 1989 amounts to 30,656,805 tonnes (33,792,775 tons) containing 106.49 tonnes (117.39 tons) of gold at an average grade of 3.46 g/tonne (0.101 ounces per ton).

8.3.1. Regional Geological Setting

The Pamour # 1 Mine lies northeast of the City of Timmins, within the northeastern part of the Porcupine camp. Mineralization occurs in basaltic and komatiitic metavolcanic ("Keewatin") rocks of the Tisdale assemblage (Section 4.5) and metasedimentary rocks of the Timiskaming assemblage (Section 4.7: Fig. PAM1). Regional studies of Whitney Township (Piroshco and Kettles 1988) indicate that the Pamour #1 Mine is located on the north limb of the east-trending North Tisdale Anticline; however, evidence in support of this interpretation comes from a more regional perspective, not afforded in the restricted corridor exposed by mine workings. In the mine area the overturned metavolcanic rock sequence of the Tisdale assemblage ("formation IV", "Tisdale Group" of Pyke 1982) dips to the north, but faces to the south. Elsewhere in the Porcupine camp, deformation of the metavolcanic rocks was followed by the emplacement of quartz-feldspar porphyry intrusions along lines of weakness that are essentially co-planar with early fold axes. In the Pamour #1 Mine area, quartz-feldspar porphyry intrusions are not abundant. The final intrusive event was the emplacement of Matachewan diabase dikes which cross-cut all previous lithologies and structures.

8.3.2. Detailed Geology

Mineralization in the Pamour #1 Mine is situated on part of a mineralized zone that is five kilometres in length. This mineralized zone straddles the unconformable contact between the metavolcanic rocks of the Tisdale assemblage ("Tisdale Group"; Pyke 1982) to the north and metasedimentary rocks of the Timiskaming assemblage ("Porcupine Group"; Pyke 1982) to the south (Fig. PAM1).

8.3.2.1. Metavolcanic Rocks

Rocks of the Tisdale assemblage ("Tisdale Group"; Pyke 1982) consist of pillowed and massive, magnesium-rich komatiitic basalts, interlayered with massive, generally concordant, lenses of talc-chlorite or carbonate rock up to 200 metres thick, containing local remnant spinifex textures. These lenses are interpreted to represent altered, mafic to ultramafic komatiitic flows. These metavolcanic rocks lie unconformably below a sequence of metasedimentary rocks (discussed below) which crop out to the south.

8.3.2.2. Metasedimentary Rocks

Above (south of) the unconformity are the clastic metasediments of the Timiskaming assemblage which have been termed the "Three Nations Lake formation" (Pyke 1982). This sequence commences with a discontinuous "agglomerate" unit which has a maximum thickness of 15 metres. This unit contains fragments of the underlying metavolcanic rocks and was deposited in depressions on the paleo-surface of the underlying metavolcanic sequence. Recent observations suggest that, at least locally, this unit is a fault breccia.

The "north greywacke" (18 metres thick) was deposited on top of, and to the south of, the agglomerate. It is black to dark grey in colour, very fine grained and thinly bedded.

The lenticular "Pamour conglomerate" is the next unit. It is an economically important host to gold mineralization. Its thickness attains a maximum of 21

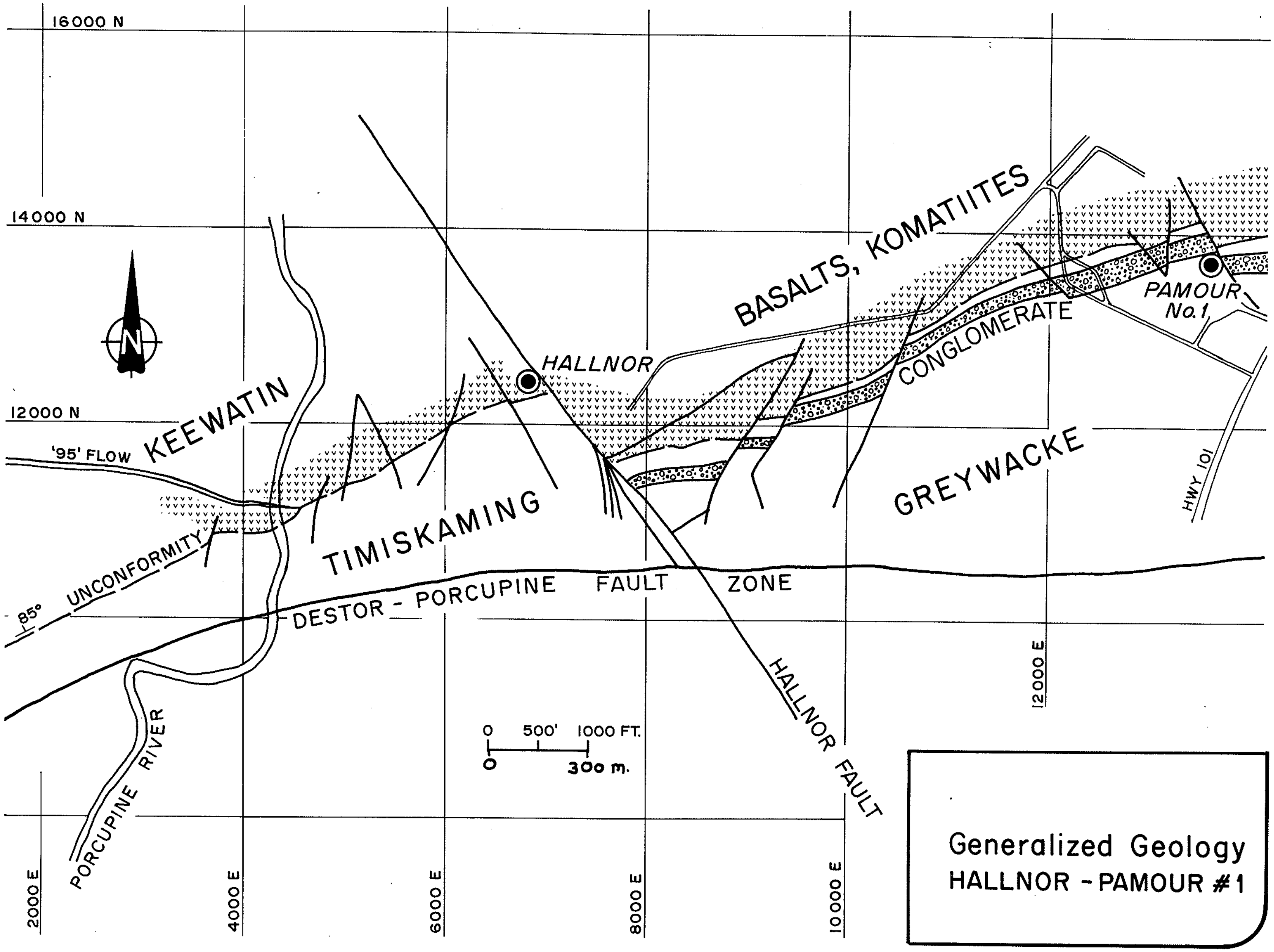

Figure PAM1: Generalized geology of the Pamour #1 Mine area.

metres, but decreases to a few metres, down dip, on the 2400 level and to the east on the adjacent Hoyle Property (see Section 8.4). The conglomerate is heterolithic, poorly sorted with well rounded, but flattened clasts set in a siliceous matrix.

The "south greywacke" is a turbiditic wacke-siltstone sequence between 180 metres and 300 metres thick. Beds vary in thickness from a few centimetres to six metres.

A second conglomerate, the Hallnor-Broulan conglomerate, is a coarse-grained rock with a limited assortment of pebbles. This conglomerate grades into an interbedded quartzite-wacke sequence. The quartzite has relatively poorly sorted grains, a coarse-grained texture and is thickly bedded.

8.3.2.3. Destor-Porcupine Fault Zone

A talc-chlorite schist zone on the southern property boundary is interpreted to demarcate the Destor-Porcupine Fault zone.

8.3.2.4. Late Intrusions

The only major intrusive bodies in the mine are two Matachewan diabase dikes. They occur in the eastern part of the mine property and cut all other structures. They dip steeply to the east, strike northwest and vary from two to thirty metres in thickness. Minor albitite dikes have also been reported.

8.3.2.5. Structure

The east-striking rocks of the Tisdale assemblage ("Tisdale Group"; Pyke 1982) are south-facing, overturned, and have variable north-dips ranging from 40° to 80°. They lie unconformably against the metasedimentary rocks to the south. The south-facing rocks of the Timiskaming assemblage have a strike of 070° and dip approximately 75° to the north. An exception to these attitudes occurs in the west end of the mine where a tight, Z-shaped drag-fold was formed by the movement of the north side to the east.

South-facing directions as determined from pillow tops and bedding structures in the metasedimentary rocks indicate that the mine is situated on the overturned north limb of a syncline. The south limb of this syncline appears to have been truncated by the Destor-Porcupine Fault zone.

Two major north-striking faults cross the property. The first, the Pamour Main Fault, is immediately east of the main shaft. It strikes north-northwest and dips 60° to the east. The Hallnor Main Fault, at the west end of the property, has a northwest strike and a dextral offset of 300 metres.

There are two systems of less pronounced faults which form a conjugate set. The major set strikes northwest and faults of this set have dextral displacements of up to 18 metres. Faults of the minor set strike northeast and have sinistral displacements of the same magnitude. These two fault systems appear to be more persistent in the metasedimentary rocks than in the metavolcanic rocks, in part due to a lack of markers in the latter.

A set of east-striking thrust faults, having 30° south dips, are associated with up to six metres of offset. They appear in the metasedimentary rocks in the lower levels of the mine.

8.3.3. Mineralization

The styles of mineralization observed at Pamour #1 vary according to host rock competency (Fig. PAM 2). Zones of brittle fracture are the principal host structure in the metasedimentary rocks, particularly in the conglomerate. The only rock types which, so far, have not yielded ore are the Hallnor-Broulan conglomerate and the interbedded quartzite-wacke unit, which lies to the south of the unconformity. Gold in the Pamour ores is typically electrum, an amalgam of gold and silver with Au:Ag ratios averaging 20:1, but locally 4:1.

8.3.3.1. Flat Vein Zones

These zones consist of quartz-carbonate-sulphide stringer veins and veinlets, striking 020° to 050° and dipping 35° to 65° southeast. Grades average 3.5 g/tonne. The fracture zones form lenticular en echelon orebodies up to 250 metres long, 25 metres thick and 60 metres vertically, that plunge to the northeast (Fig. PAM3). Within the zones, individual veins may be spaced a few centimetres to several metres apart and may vary from a few millimetres to several centimetres in thickness. In general, the grade of gold mineralization varies

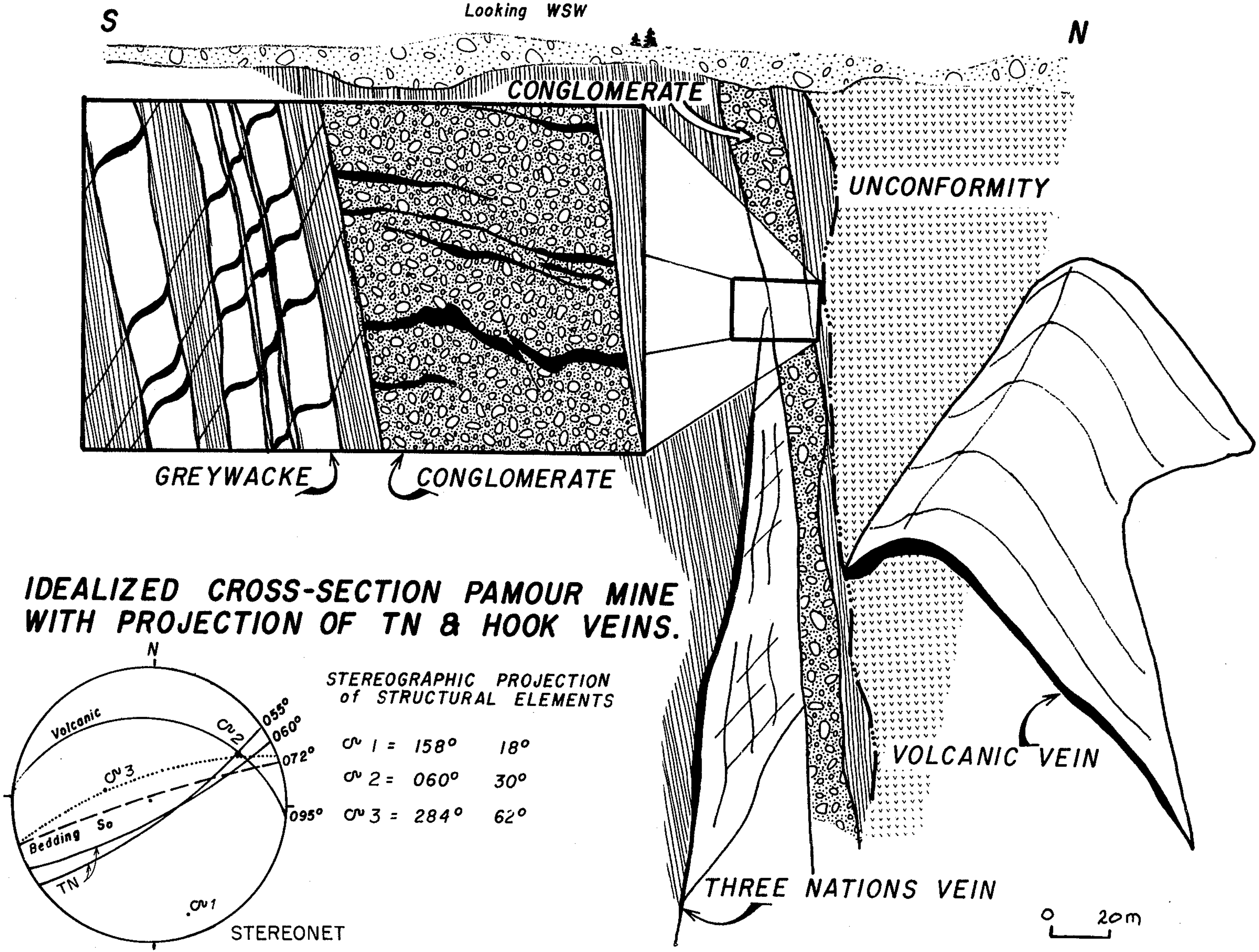

Figure PAM2: Schematic styles of quartz veins in the Pamour #1 and Hoyle Mines (see Section 8.4. for a description of the Falconbridge Hoyle Mine).

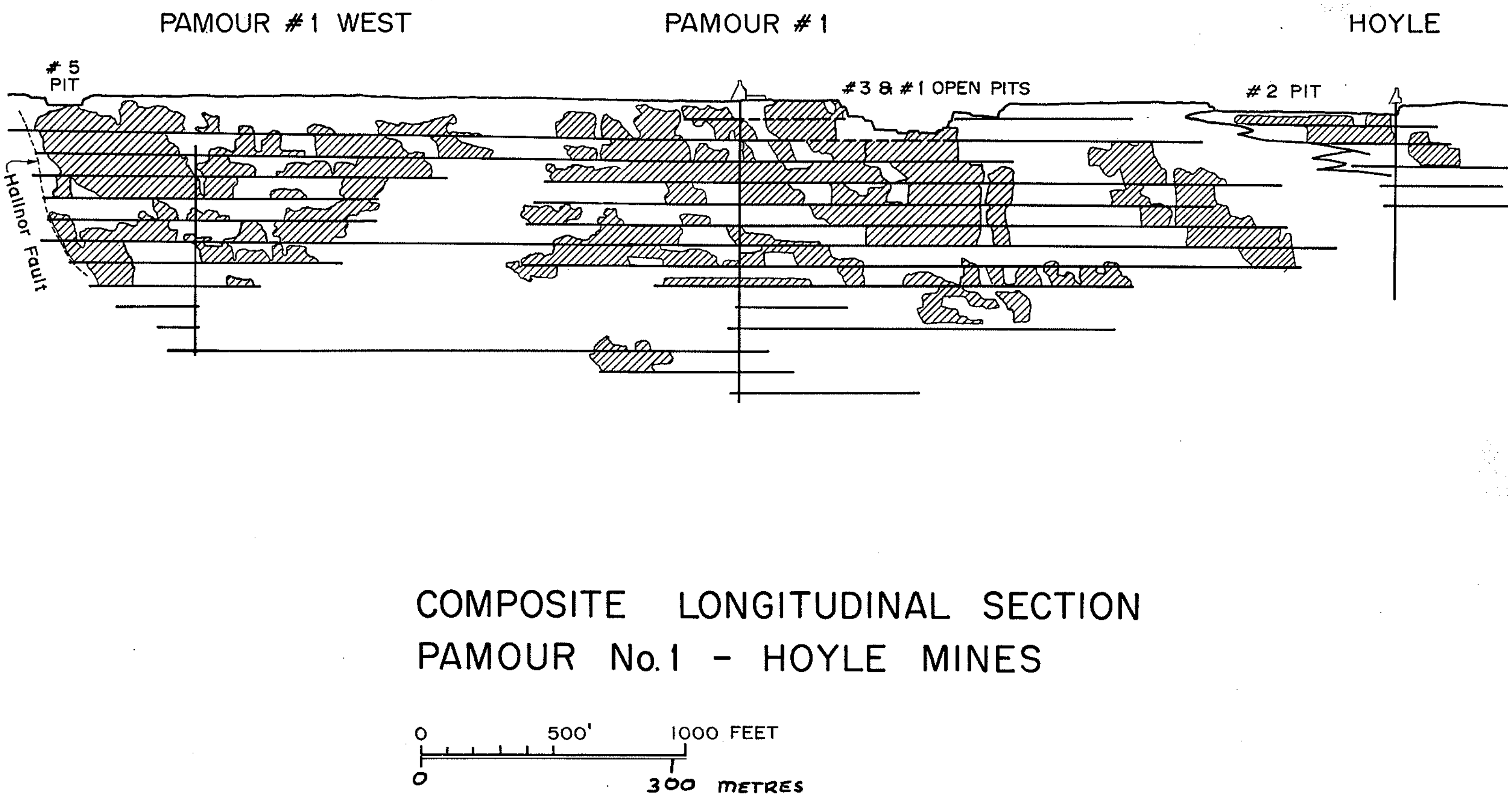

Figure PAM3: Composite longitudinal section for the Pamour #1 and Falconbridge Mines (see Section 8.4. for a description of the Falconbridge Hoyle Mine).

directly with vein frequency. Associated sulphide phases include pyrite, pyrrhotite and arsenopyrite, which impregnate both matrix and clasts of the conglomerate. Minor chalcopyrite and sphalerite are present locally. Intensity of replacement of clasts differs widely from clast to clast. Some appear to be completely pyritized, while others are totally devoid of sulphides. Sulphide minerals occur in both matrix and altered wall rock. Sphalerite has only been observed within the quartz veins, suggesting it was late stage. Gold occurs in quartz veins, either in a free state, or as minute inclusions within sulphide minerals.

Sets of auriferous flat veins of the same style are also found in the "mine wacke", a unit that comprises alternating bands of wacke and argillite. Gold occurrences are largely restricted to quartz veins within the interlayered wacke units. Quartz veins within the argillite layers appear refracted and considerably thinned. A comparable style of mineralization occurs locally within the metavolcanic rocks to the north of the conglomerate, within a few metres of the contact.

8.3.3.2. Single Vein Style

A second style of mineralization occurs in the wacke units and usually consists of a single vein-type structure. Typically these veins have an east strike, dip between 80° south and 80° north, and are composed primarily of quartz and carbonates with minor tourmaline and sulphides. Although qualitative, the presence of arsenopyrite is indicative of higher gold grades, and the presence of chalcopyrite and sphalerite is indicative of very good gold grades. These veins have an average grade of 3.77 g/tonne. A variety of this style of mineralization is the "T.N.-type" vein. These veins are narrow quartz-tourmaline stringers, commonly of high grade.

8.3.3.3. Ribbon Veins

Within the metavolcanic rocks, there are well-developed veins consisting of quartz and carbonate with minor tourmaline, calcite and chlorite, as well as black sphalerite, pyrite and chalcopyrite. These veins are typically the highest grade mined, averaging 6.38 g/tonne. They strike east, and dip 30° to 50° north. They commonly exhibit well-developed ribbon textures with many inclusions of wall rock, suggestive of repeated episodic opening and filling (crack-seal). Major veins, such as "51-Vein", are in some cases as much as 600 metres in strike length, with a similar vertical extent. Gold in these veins is erratically distributed ("nuggety") with apparently random, or at least irregular distribution. In the "62-Vein", pockets of extremely high-grade ore showing very coarse gold are separated by extensive sections of barren to low grade vein material. In the "51-Vein", the higher grade ore (12 g/tonne) appears to be localized in the peripheral 150 metres of the vein, with the gold content dropping off gradually with increasing distance away from the top of the vein. The central part of the vein is generally of marginal- to waste-grade. Within the ore zones, the vein usually follows a flow contact where the hanging wall is pillowed basalt and the footwall is a komatiitic flow. Where the vein comes in contact with a highly altered ankeritic flow unit, the gold content tends to drop off rapidly. Locally, veins transgress stratigraphy.

8.3.4. Rock Alteration

The conglomerate found at the Pamour #1 Mine has been only slightly altered. Feldspars are a principal mineral constituent and are essentially unaltered. The weakly developed foliation suggests stress was accommodated by brittle failure along discrete surfaces, although the presence of flattened clasts indicates that the area experienced a component flattening. Within the ore zones within conglomerate and greywacke, the rock has a bleached appearance and it is apparent that certain pebbles and greywacke beds have been affected more than others. Units of fine-grained sediments within the conglomerate and of siltstone beds within the turbidite sequence have been only slightly affected. Argillite layers in ore zones within wacke acted as effective blocks to both alteration and the extension of quartz-filled fracture systems. Similar characteristics occur in the minor ore zones of the same type within the metavolcanic rocks.

Early studies of the alteration associated with the east-striking steep veins in the metavolcanic rocks indicated that there were conspicuous gains in sulphur and potassium and a marked loss of silica. Intense pyritization, or the introduction of sulfur, resulted in a loss of both silica and carbonate. Alumina content remained essentially unchanged.

Mineralogical changes associated with alteration surrounding quartz veins in the metavolcanic rocks include the replacement of: 1) feldspars by sericite, epidote, carbonate and quartz; 2) chlorite and other ferromagnesian minerals by carbonate, quartz and pyrite; and 3) carbonate by pyrite.

Observations of the alteration associated with the "51-Vein" indicate that a carbonate halo extends 100 metres into the wall rock. Ferroan dolomite (ankerite) occurs closest to the vein and calcite occurs more distant from the vein. Various mineral assemblages composed of chlorite, carbonate, albite and sericite constitute the main alteration minerals. The pattern indicates the addition of potassium, carbon dioxide, arsenic, sulphur and calcium to the wall rock and depletion of sodium.

Potassium, carbon dioxide and sulphur are concentrated in the hanging wall of the vein and the intensity of carbon dioxide and hydrogen ion metasomatism increases upward in the mine together with an increase in gold values from an average of 3.4 g/tonne on the 1400 level to 8.6 g/tonne at the 800 level.

8.3.5. Temporal Constraints

Cross-cutting relationships indicate that the quartz veins formed following the sedimentation of the Timiskaming-like metasedimentary rocks. However, because of the absence of late Archean porphyry intrusions in the mine stratigraphy, it has not been possible to establish how long after sedimentation the veins formed. Also, regional structural studies only allow a general correlation between vein formation events here and in other parts of the Porcupine camp.

8.3.6. Tour Guide

A possible combination of an underground and surface tour will be arranged immediately before the group arrival; however, because of the active mining, it is not possible to summarize the details of this tour at present.

Falconbridge Hoyle Mine, Whitney Township

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P4N 7X7

Located twenty kilometres east of Timmins, the Hoyle Property has been intermittently mined on extensions of the Pamour No. 1 stratigraphy. During its main period of operation from 1941 to 1948, 2,188,438 grams of gold were produced from 659,539 tonnes of conglomerate ore. From 1978 to 1980, minor amounts of ore were mined from 400 level development and the #2 open pit. The Hoyle Property is owned by Falconbridge Gold Limited, and optioned to Giant Yellowknife Mines Limited on a tonnage royalty basis.

Gold is associated with quartz-ankerite-pyrrhotite veins and stockworks and with minor sulphide mineralization (pyrrhotite +/- pyrite). A zone of favourable stratigraphy, 915-metres in width, strikes east-northeast across the property for three kilometres. These rocks are overturned and dip to the north at 60° to 80°. To date, most production has come from conglomeratic unit (Pamour conglomerate), six to thirty metres in thickness, that is close to the unconformity which separates Archean metavolcanic ("Keewatin") rocks to the north from the Timiskaming-like metasedimentary rocks to the south. Veins found in the metavolcanic rocks are usually of significantly higher grade than those in the conglomerate or greywacke. The Destor-Porcupine Fault zone traverses the southernmost claims. Table PHOYLE1 outlines the historical development of this property.

Table PHOYLE1: Historical summary of mining and exploration activity of the Falconbridge Hoyle Mine.

1934-1938: Exploration by Hollinger and later by Ventures Limited.

1938-1940: Construction and underground development.

1941-1943: Production stopped by mill fire in 1943.

1943-1945: Care and maintenance.

1945-1948: Production, custom milling at Pamour.

1948-1979: Dormant.

1979-1981: Ramp and level development.

1981-1989: Dormant.

1989-Present (1990): Development and production by Giant Yellowknife Mines Limited with ore being milled at Pamour No. 1.

The property consists of thirty-seven patented claims and is located twenty kilometres east of Timmins. Highway 101 crosses the northwest corner of the property and a 400-meter all-weather connecting road leads to the mine site. The Ontario Northland Railway line is located less than 1.5 kilometres to the north.

8.4.1. Regional Geological Setting

Lithologies exposed on the Falconbridge Hoyle property include basaltic komatiites and magnesium-rich tholeiitic basalts of the Tisdale assemblage (Section 4.6.; "formation" IV, Tisdale "group") and metasedimentary rocks of the Timiskaming assemblage (Section 4.8.). Conglomerates, arkosic wackes, and argillite of the Timiskaming assemblage unconformably overlie the older Tisdale assemblage.

The Hoyle Property lies on the north flank of the Porcupine Syncline. From south to north, the overturned sequence consists of Timiskaming-like metasedimentary rocks, metavolcanic rocks of the Tisdale assemblage, and metasedimentary rocks of the Hoyle assemblage (Section 4.4; Fig. PHOYLE 1). The Destor-Porcupine Fault, marked by a zone of serpentinized ultramafic rocks, crosses the southern edge of the property. It is essentially parallel to the metasedimentary rock sequence, south of the unconformity that strikes east-northeast and dips 60° to 80° to the northwest. Randomly spaced, near vertical diabase dikes, up to 40 metres in width, cross-cut stratigraphy and strike north-northwest. A set of post-ore cross faults, striking north-west and north-northeast, have inferred horizontal displacements of up to 120 metres, based on drill information.

8.4.2. Detailed Geology

Outcrop is confined to metavolcanic rocks of the Tisdale assemblage in the immediate mine area (as mapped by Dr. Duncan Derry in 1933) and a 1.5 kilometre long ridge of Timiskaming-like metasedimentary rocks, exposed to the south and southwest of the mine area. Total exposure is approximately five percent. Overburden thickens to the east, varying in depth from six to twenty metres.

8.4.2.1. Metavolcanic Rocks of the Tisdale Assemblage

As originally mapped by Derry (1933), the metavolcanic rocks north of the unconformity include magnesium-rich tholeiitic basalt and lesser amounts of basaltic, pyroxenitic and ultramafic komatiitic flows. Alteration of these rocks has produced carbonate-, talc-carbonate-, and serpentine-rich assemblages. In drill holes, the same stratigraphy has been identified as basalt, greenstone, soapy basalt, serpentinized and carbonated lava, and lava. On the adjacent Pamour #1 property, the same rock units have been designated andesite pillow lava, carbonated lava and talc-chlorite rocks. The metavolcanic rocks strike east-southeast and dip at 35° to 70° to the north, in contrast to the metasedimentary rocks south of the unconformity. A lack of data precludes any meaningful structural interpretations of the Hoyle Property, except on surface where Derry's mapping indicated the stratigraphic sequence had been folded into an anticline.

8.4.2.2. Metasedimentary Rocks of the Hoyle Assemblage

A sequence of wackes, slates, and argillites that occur as subcrop near the northern boundary of the property, either conformably underlie or have been conformably thrust under the Tisdale assemblage metavolcanic rocks. The contact between the metavolcanic and metasedimentary rocks of the Tisdale and Hoyle assemblages respectively strikes easterly across the northern part of the Hoyle property for a distance of 1,500 metres.

8.4.2.3. Timiskaming-like Metasedimentary Rocks

The metasedimentary rock series comprises a basal conglomerate (variously described as an agglomerate or basal breccia), overlain by a sequence of wackes, conglomerates, slatey wackes, slates and quartzites. A polymictic conglomerate, called the "Pamour conglomerate", occurs towards the base of the sequence. The thickness of the sequence exceeds 750 metres. The Timiskaming-like metasedimentary rocks are bounded on both sides by older metavolcanic rocks. The northern contact is interpreted to be an unconformity, although recent observations suggest there was at least some movement on this surface. Both the younger Timiskaming-like metasedimentary rocks and the older metavolcanic rocks face to the south, but dip to the north and therefore are overturned. The relationship between the metasedimentary rocks and the

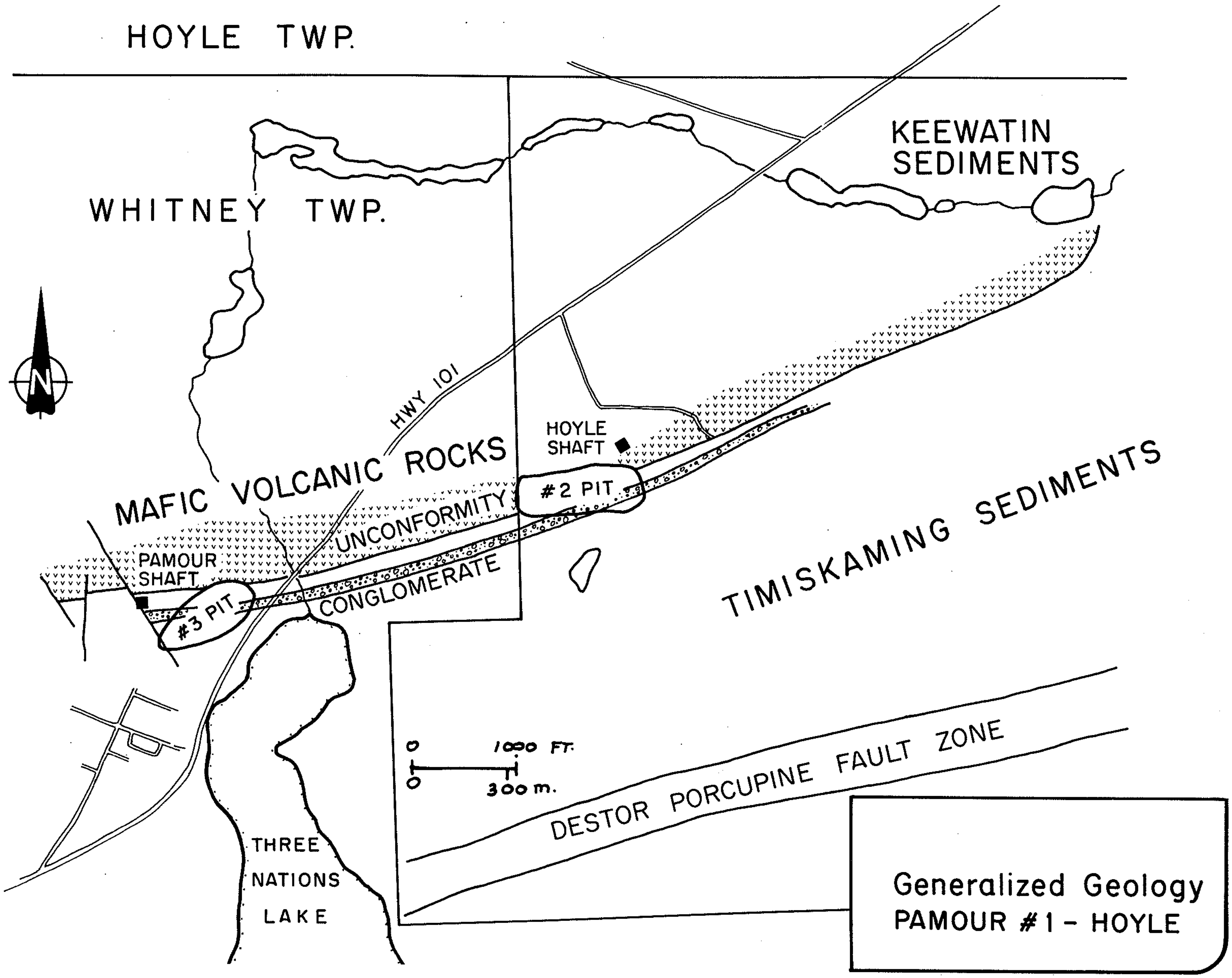

Figure PHOYLE1: Generalized geology of the Pamour #1-Hoyle Mine area. "Keewatin" sediments belong to the Hoyle assemblage and are interpreted to pre-date the deposition of the Timiskaming-like sediments.

metavolcanic rocks to the south has not been observed, but the coincidence of the Destor-Porcupine Fault zone with the contact suggests it may be a structural discontinuity.

The (unconformable) contact between the Timiskaming-like metasedimentary rocks and the older metavolcanic rocks to the north has been traced for more than 3,000 metres across the property by diamond drilling.

8.4.2.4. Destor-Porcupine Fault Zone

The fault lies parallel to, and about 1,000 metres south of, the northern unconformity which separates the older metavolcanic rock from the Timiskaming-like metasedimentary rock. No outcrops occur and no diamond drilling has been carried out on this structure.

8.4.3. Mineralization

All rock types can contain auriferous quartz veins. Gold-values are positively correlated with the presence of pyrrhotite and pyrite, and are strongly positively correlated with the presence of arsenopyrite, galena, and sphalerite. These latter three sulphide minerals are only minor constituents of the mineralized material. Bleaching, silicification and sericitization are commonly associated with the gold mineralization.

On the Pamour and Hoyle properties, early exploration and production was from a conglomerate horizon (Pamour conglomerate), which ranged in thickness from six to thirty metres, and ranged in grade from 2.26 to 3.67 g/tonne Au. Subsequently, on the Pamour property, considerable tonnages have been mined from veins in the greywacke (2.83 g/tonne. Au) and from veins (up to 14 g/tonne Au) and disseminated zones or stockworks in the metavolcanic rocks. Economic mineralization may be localized in fractures within relatively brittle rocks, as a result of slight changes in dip or strike.

The following descriptive classification of mineralized zones is adapted from Paransevicius (1967).

8.4.3.1. Wide Disseminated Zones

These orebodies are developed in the "Pamour conglomerate" and south wackes, although they also occur in the agglomerate. They are characterized by closely spaced quartz veins, which strike 020° to 045° east, dip 10° to 70° to the southeast, and range in width from 2.5 centimetres to several metres. The ore zone includes both veins and the adjacent, altered wall rock. Pyrite and pyrrhotite are common sulphide minerals. Gold occurs either free as grains in the quartz or as minute particles in the sulphides.

8.4.3.2. Tabular High Grade Veins

These veins occur in the metavolcanic rocks and are subdivided into two types: a) thin, with abundant sulphides; b) thick, with rare sulphides. Both types have westerly strikes and dip between 30° and 55° to the north. The wall rock is only slightly altered. The veins and alteration tend to follow the contacts of the metavolcanic flows.

8.4.3.3. Tabular Low Grade Veins

These quartz veins, which occur in the south greywacke, have a general east strike and a dip of between 70° south and 80° to the north. They may have a strike length of up to 500 metres, a width of 0.15 to 3.7 metres, and can persist for 370 metres vertically. The veins cut the wacke bedding planes at an acute angle. Wall rock bleaching is attributed to replacement by sericite, which is accompanied by pyrite. In general, gold-values are found where the bleaching is pronounced. Gold occurs either free in the quartz or as minute particles in the pyrite within the altered wall rock.

8.4.4. Tour Guide

Due to the dynamic changes which accompany an active mining situation, the tour itinerary will be presented immediately before the visit.

Hoyle Pond Mine

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The Hoyle Pond Mine is located 18 kilometres east of Timmins in the southwest part of Lot 3 Concession II and the northwest part of Lot 3 Concession I, Hoyle Township. In 1969, while Texasgulf attempted to follow the favourable horizon which was being delineated by Canico at the adjacent (and stratigraphically younger) Owl Creek deposit, discovery hole 69-17 intersected 6.5 g/tonne Au over three metres in carbonated, magnesium-rich, tholeiitic basalts. Subsequent surface drill programs in 1980 and 1982 yielded enough encouraging results for it to be decided to proceed with the development of a decline access in late 1983. Positive results in the feasibility stage led to a production decision and, to date, this mechanized cut and fill operation has mined 450,000 tonnes at 18.3 g/tonne gold.

8.5.1. Regional Geological Setting

The Hoyle Pond Mine occurs within the Tisdale assemblage (historically known as "Tisdale Group"; Pyke 1982), 4.5 kilometres north of the Destor-Porcupine Fault. The Hoyle Pond Mine occurs in a sequence of south-facing, 065° striking, steeply north-dipping, magnesium-rich tholeiitic basalts (Downes et al. 1984; Fig. FHOYLE1 and FHOYLE2). This overturned sequence is interpreted to be time equivalent with the lower parts of the Tisdale assemblage ("formations" IV and V of the Tisdale "group"; Pyke 1982; Table FHOYLE 1), defined by mapping in the Porcupine Syncline area, further to the west (Pyke 1982). This sequence is cut by northwest- and north-northeast-striking, steeply dipping faults, and intruded by north-striking Matachewan diabase dykes. Several vein types have developed due to structural conditions and exhibit varied alterations and mineralogies (Fig. FHOYLE2).

8.5.2. Detailed Geology

"Formation" IV of the "Tisdale Group" (Pyke 1982) hosts the Hoyle Pond mineralization. This sequence is equivalent to the Tisdale assemblage, when considered on a larger scale (Section 4.5). Various workers have described aspects of the stratigraphy (Downes et al. 1984; Karelse 1985; Geology Staff 1984-1990) and a summary is presented here.

8.5.2.1. Northern Greywacke

This stratigraphically lowest unit has been examined in drill core only. Interbedded arkosic wackes and argillites show well developed Bouma sequences, identifying this unit as a distal turbidite. Striking 085° to 090° and dipping 75° to 85° north, this unit is foliated sub-parallel to well developed bedding near its upper contact. Rare pyrite cubes, five to ten millimetres in diameter, as well as quartz and/or calcite stringers up to two millimetres in width, occur sub-parallel to bedding and constitute one to two percent of the rock. The upper contact of this unit is commonly a gouge indicating a faulted or irregular surface with the overlying graphitic argillite.

8.5.2.2. Northern Graphitic-Argillite

This unit, one to five metres in thickness, may be a poorly developed turbidite, as evidenced by minor arkose-wacke beds, in a faulted sequence of carbonaceous argillites. Shiny black graphite beds and gouge sub-parallel to bedding (strike 090°, dip 75° to 85° to the north) commonly contain one to five percent, flattened pyrite nodules, one to three centimetres in diameter, which have calcite-filled pressure shadows.

8.5.2.3. Hoyle Pond Magnesium-rich Tholeiite

The basaltic component of this sequence is dominated by pillowed, magnesium-rich, tholeiitic basalts. Less than 20 percent of the sequence

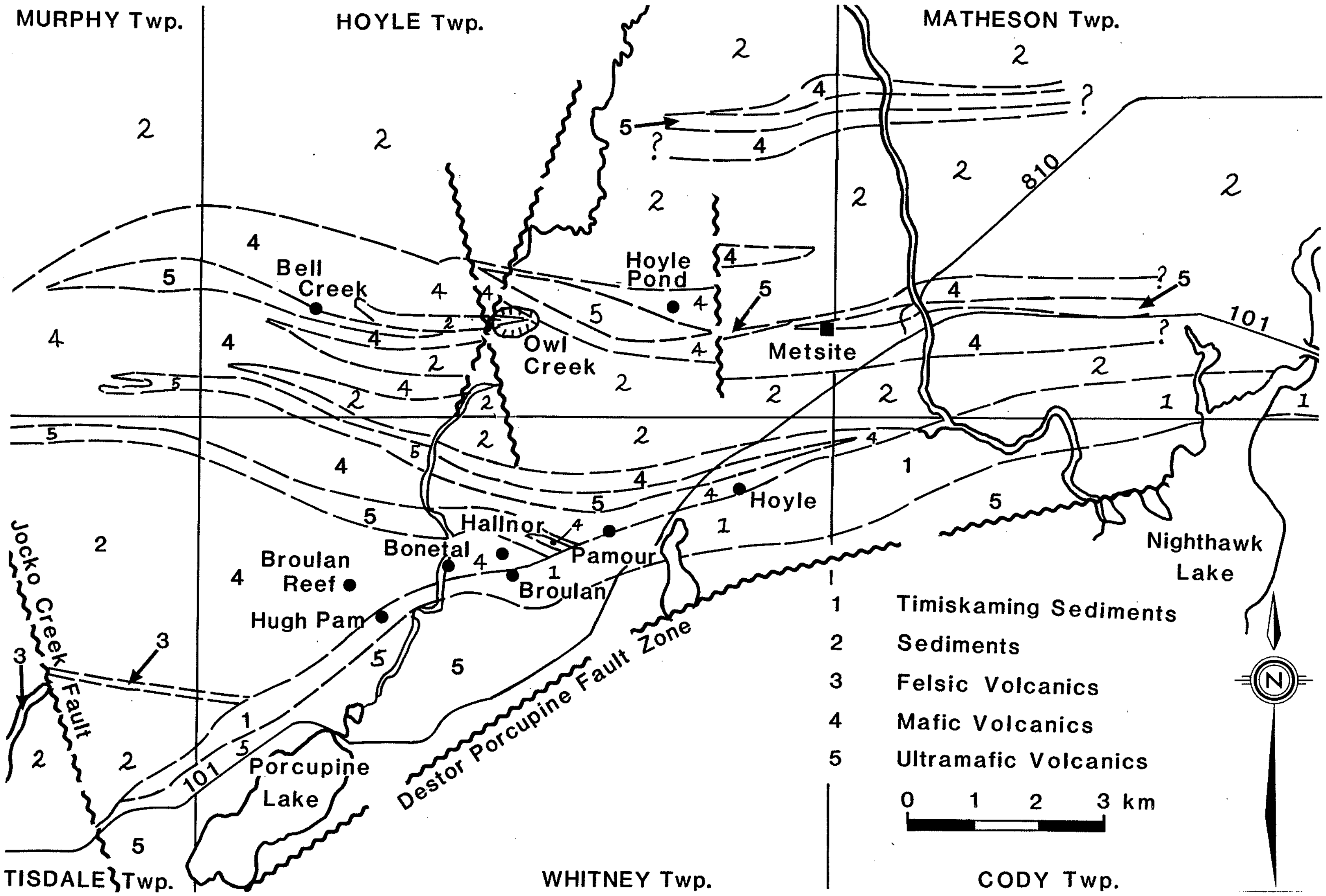

Figure FHOYLE1: Generalized geology of the Falconbridge Hoyle Pond Mine area.

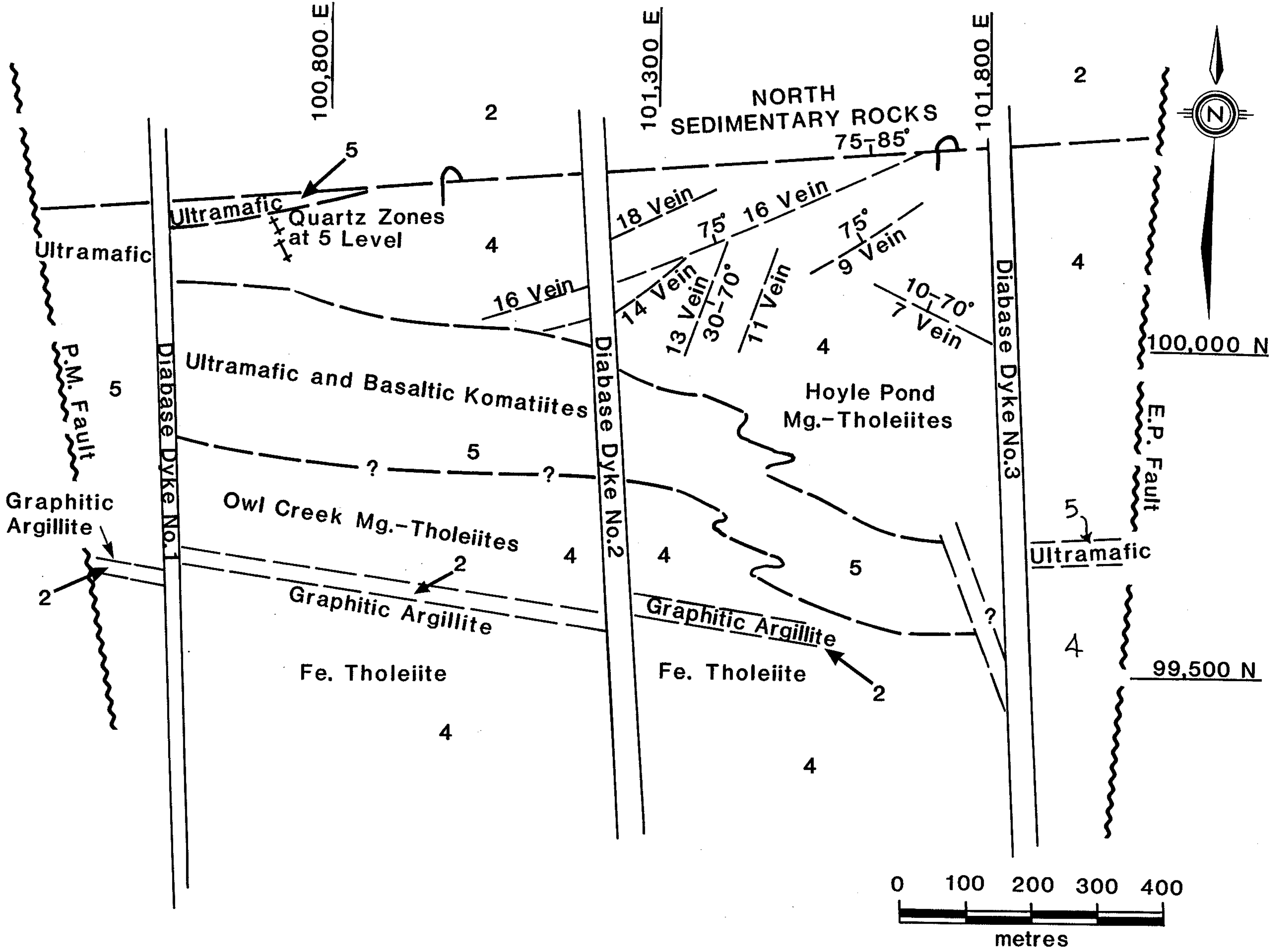

Figure FHOYLE2: Simplified plan of the Falconbridge Hoyle Pond Mine stratigraphy. P.M. Fault corresponds to the Powder Magazine fault. E.P. Fault corresponds to the Environmental Pond fault.

TABLE FHOYLE1: Correlation of stratigraphic nomenclatures with rocks observed in the Falconbridge Hoyle Pond Mine (Burrows, 1986).

TIMMINS AREA VOLCANIC STRATIGRAPHY

Group	Formation	Sub-Group	Flow No.	Hoyle Pond Equivalent
	VI			
	V	Vipond	VII	
			V10(A-D)	
Tisdale			V9	
			V8(A-F)	
			V7	
			99	Fe-tholeiite
		Central	C17	Owl Creek
			C12-16	Mg-tholeiite
	IV		55	Basaltic-ultramafic komatiite
			95 A-D	Hoyle Pond
		Northern	63B	Mg-tholeiite
			63A	
			51B	
		North of Destor-Porcupine Fault		
		South of Destor-Porcupine Fault		
Deloro	III			
	II			
	I			

consists of massive, hyaloclastite, amygdaloidal, or variolitic units. Distinguished on the basis of colour (e.g., buff, light grey, and light green) and pillow rim differences, pillowed units can be traced along strike and dip at the mine scale. "Grey zones", one to ten metres in thickness, are variously schistose and are replaced by carbon and carbonate minerals (Downes et al. 1984). These "grey zones", which are host to economic quartz veins, may be relict (brecciated) flow top horizons. In response to deformation, these zones of initial weakness served as the main channels for hydrothermal mineralizing fluids. Other economic quartz veins at various orientations do not display the dramatic wall rock alterations associated with grey zones.

Contrary to interpretations of earlier geological teams, which were based mainly on drill hole data, underground mapping by the present staff indicates that the magnesium-rich, tholeiitic basalt unit, which attains a thickness of 350 metres, lies unconformably upon the metasedimentary rocks. The metavolcanic unit has a strike of 065° and a dip of 70° to 80° to the north.

The basal part of this unit consists of a "mixed mafic" (Rye 1987) or volcaniclastic rock whose thickness ranges from two to ten metres. This is a clast supported unit, comprised of angular to subrounded fragments of variably altered, mafic metavolcanic rock and metasediments. The matrix is pyrite-, carbon- and carbonate-rich. Quartz veins localized in this unit have gold values of one to five g/tonne. The abundance of sedimentary-derived clasts decreases stratigraphically upwards.

The magnesium-rich tholeiitic basalt unit has a gradational upper stratigraphic contact with the overlying basaltic and ultramafic komatiites. This transitional contact zone is characterized by increasing schistosity and chlorite-carbonate alteration.

8.5.2.4. Komatiitic Rocks

The east-striking, 40° to 70° north-dipping, ultramafic unit ranges up to 300 metres in thickness. This unit lies south of most mine workings and has been intersected by limited surface and underground diamond drilling. The decline is collared in coarse-grained, buff-coloured "carb rock" (mine nomenclature), which forms the basal unit of the komatiites, at the west end of the Hoyle Pond Mine. A dark green, weakly to strongly schistose, chloritic, basaltic komatiite is in gradational contact with the Hoyle Pond magnesium-rich tholeiites at the east end of the mine. The core of the komatiitic package is a dark grey to dark green, variably talc-rich, locally serpentinized ultramafic rock. The most southerly and upper-most portion of the komatiitic unit appears to consist of variably carbonatized flows (spinifex noted), which interfinger with the Owl Creek magnesium-rich tholeiites.

8.5.2.5. Owl Creek Magnesium-rich Tholeiites

About 12 diamond drill holes have cut this unit, which ranges up to 150 metres in thickness. It consists of more massive and bleached sections, compared to the stratigraphically lower Hoyle Pond magnesium-rich tholeiites. Thin "grey-zones" and zones of carbonate-pyrite replacement, associated with minor quartz stringers, have been noted in the far eastern part of this sequence.

8.5.2.6. Quartz-Feldspar Porphyry

This thin unit (<five metres) occurs as dikes and possibly sills, which cut both the komatiites and the Owl Creek magnesium-rich tholeiites. It is locally replaced by sericite and carbonate, and contains five to fifteen percent subhedral-euhedral quartz and/or albite phenocrysts, and one percent disseminated, fine-grained, cubic pyrite. It has not been explored extensively.

8.5.2.7. South Graphitic Argillite

This is a well bedded, east-striking unit, two to ten metres in thickness, which has a 40° to 70° dip to the north. Graphitic gouge occurs at some contacts and minor nodular pyrite occurs locally. It demarcates the top of the Owl Creek magnesium-rich tholeiites and is the equivalent to the top of "formation" IV, Tisdale "group" (e.g., Pyke 1982).

8.5.2.8. Iron-rich Tholeiite

This 25 to 50 metre thick metavolcanic unit is medium green, medium to coarse grained, quite massive and leucoxene-bearing. It is texturally similar to, and interpreted to correlate with the "99-Flow" unit, which defines the base of "Vipond series" (Ferguson et al. 1968), also referred to as the basal unit of "formation" V of the Tisdale "Group" (Pyke 1982). Stratigraphically above this iron-rich tholeiite is a graphitic argillite, one metre thick, which is in turn overlain by at least 200 metres of monotonous, well bedded, arenaceous wackes.

8.5.2.9. Diabase

Three Matachewan diabase dikes cut the mine stratigraphy. They have a 350° strike, near vertical dips, and are 30 to 40 metres in thickness. The diabase is dark green, medium to coarse grained, weakly to strongly magnetic, and exhibits three prominent joint sets and chilled margins. Minor offsets and localized carbonate-chlorite alteration of country rock has been noted along the diabase dikes.

8.5.3. Geochemistry

The average gold abundance in mafic and ultramafic metavolcanic rocks is less than or equal to 10 ppb, and a concentration factor of 100 to 1000 is required to generate an economically exploitable concentration. If gold is derived and concentrated from these rocks, the source volume must be of regional extent (Jensen 1980).

The most recent whole rock work (Rye 1987) is summarized in Table FHOYLE 2. Samples with field names ranging from ultramafic komatiite through to magnesium-rich tholeiite, collected on two and three levels underground at the Hoyle Pond Mine, were analysed and are plotted on Jensen plots for comparison. Komatiites are characterized by lower SiO_2, Al_2O_3, MgO, total iron, Na_2O and larger CaO abundances than average komatiites found elsewhere in the Timmins-Kirkland Lake area. Basaltic komatiites are comparable in composition to ultramafic flows (e.g., low SiO_2, TiO_2, and alkalis, and high CaO) as indicated from published averages. Magnesium-rich tholeiitic basalts are very similar to average tholeiite compositions except for less TiO_2. Detailed work has shown carbon and potassium enrichments and silica depletions towards the core of "grey zones" developed in schistose magnesium-rich tholeiites (Downes et al. 1984; Rye 1987).

8.5.4. Structure

The contact between metasedimentary and metavolcanic rocks north of the Hoyle Pond Mine appears to represent an angular unconformity, suggested by mine mapping data. Intercalation of metasedimentary rocks within the Tisdale "group" metavolcanic rocks suggests that: 1) early fault-bounded basins, with faults running north-northwest, preserved and were active after rotation of strata into their present position; or 2) folding and erosion of strata took place prior to rotation of rock sequences into their present position. Regional north-south compression rotated and overturned strata and caused the development of an early shear zone which is host to the "16-", "15-", and "9-veins" (Duff, Geologist, Falconbridge Limited, personal communication 1990).

8.5.4.1. Mine-scale Structure

Lower greenschist facies regional metamorphism and carbonate-chlorite alteration, accompanying the emplacement of the basaltic-ultramafic komatiites, helped render the Hoyle Pond magnesium-rich tholeiites brittle. East-west deformational forces, focused along the contact between the northern graphitic argillite and magnesium-rich tholeiite, caused the development of shears along zones of previous weakness (carbonaceous flow top?). A wrench-fault is postulated at the contact between the northern graphitic argillite and the magnesium-rich tholeiite. A variety of tension and shear veins, as well as reverse faults and folds, similar to those described by Colvine et al. (1988) and McClay (1987), are observed in the Hoyle Pond magnesium-rich tholeiites. Flow tops served as loci for some of the mineralization and dilational fracturing along these flow contacts may have resulted from high fluid pressures. Boudinage structures of the quartz veins in the "16-vein" and the plunges of the ore zones within the "16-", "14-", "13-", and "11-veins" seem to record more than one phase of deformation. Somewhat enigmatic is the fact that west of the No. 2 diabase dike, both "16-" and "14-veins" are folded in a similar style and have been reversely faulted with little apparent effect on country rock.

8.5.5. Mineralization

Vein mineralogy has been summarized in Table FHOYLE 3. Gold from the Hoyle Pond Mine consistently averages 92 percent gold and eight percent silver (Karelse 1985). The majority of the gold occurs as free gold in stylolites in "16-" and "14-veins" or as fracture controlled blebs in all veins. Positive correlations between gold and chalcopyrite, and gold and sphalerite, have been noted in "16-", "14-", "13-", "11-veins".

8.5.6. Rock Alteration

Spilitic alteration of original rocks resulted in development of greenschist facies assemblages (Rye 1987). Some early zones of structural weakness, such as flow tops, and intercalated graphitic argillites, which may have had variable carbon contents (i.e. similar to "3-", "5-", and "25-veins" at McIntyre Mine; D. Brisbin, Senior Mine Geologist, Falconbridge Limited, Kidd Creek Mine, personal communication, 1990) served as channelways during periods of high fluid pressure. "Grey zone" alteration was localized in these permeable zones, which are the loci for "16-", "15-", and "9-vein" mineralization (Table FHOYLE 4).

Mapping of "14-", "13-", "11-", and "7-veins" has shown that these veins crosscut, and, therefore, are younger than stratigraphy, but are associated with little apparent alteration of the country rock. A halo,

TABLE FHOYLE2: Representative chemical analyses of rocks from the Falconbridge Hoyle Pond Mine area (from Rye 1987).

	ULTRAMAFIC KOMATIITES			COMPARATIVE GEOCHEMICAL ANALYSES			THOLEIITIC BASALTS		
				BASALTIC KOMATIITES					
	Hoyle Pond	(2) Condie	(6) Wilson	Hoyle Pond	(4) Condie	Hoyle Pond	"Ore Zones"	(5) Condie	(6) Wilson
SiO_2	28.0	42.9	41.0	43.2	48.8	47.0	41.9	50.2	49.4
Al_2O_3	3.95	7.46	4.40	8.67	13.0	16.0	14.0	15.5	14.1
CaO	13.5	7.21	4.27	10.6	8.24	7.10	10.4	11.6	8.94
MgO	17.5	24.0	28.43	13.3	11.8	7.11	5.77	7.53	6.17
Na_2O	0.10	0.41	0.36	0.83	1.48	2.15	1.98	2.15	2.33
K_2O	0.10	0.16	0.05	0.02	0.15	0.33	0.61	0.22	0.33
Fe_2O_3	8.21	10.1	10.3	12.2	12.7	10.2	8.19	11.9	13.1
MnO	0.28	0.19	0.15	0.23	0.21	0.22	0.25	0.22	0.22
TiO_2	0.26	0.36	0.28	0.55	0.73	0.51	0.45	0.94	1.16
P_2O_5	0.04	0.02	0.01	0.43	0.09	0.06	0.04	0.10	0.17
CaO/Al_2O_3	3.42	0.97	0.97	1.22	0.63	0.44	0.74	0.75	0.63
Al_2O_3/TiO_2	15.2	20.7	15.7	15.7	17.8	31.4	31.1	16.5	12.2
Na_2O/Na_2O+K_2O	0.91			0.98		0.85	0.77	0.91	0.88
Cr ppm	1600	2200	2191	2201	900	233.8	348.0	490	256
Ni	650	2000	1463	525	390	110.2	140.2	140	162
Co	59	60	90	66.5	270	52.1	47.7	52	38
As	81			9.5		29.1	100.0		
W	82			1.0		60.9	69.1		
Rb	20			11.7		20.0	26.4		
Sr	90		39	21.7		50.0	61.8	100	149
Y	10	10		10.0	22	15.9	14.5	20	
Zr	20	34	56	10.0	69	21.8	14.5	53	108
Nb	20			16.7		15.9	10.0		
Ba	18.2		14	31.7	37	133.5	137.5	80	99
Sc	110	90	181			50.6	47.1		
Au ppb	10			10.5		14.2	3657	260	385
Ti/Zr	77.9			329.7		140.3	186.1	106.3	64.4

1. Total iron as Fe_2O_3
2. Condie (1981): Average spinifex-textured peridotitic komatiite, Abitibi Belt
3. Wilson and Morrice (1977): Average peridotitic volcanic Timmins, Kirkland Lake
4. Condie (1981): Average basaltic komatiite BK2
5. Condie (1981): Archean tholeiite TH1
6. Wilson (1977): Average Superior Province tholeiite

TABLE FHOYLE3: Summary of structural and vein characteristics and mineralogy in the Falconbridge Hoyle Pond Mine.

VEIN NO.	STRUCTURAL CONDITION	MINERALOGY
16 (15)(9)	Sub-parallel to stratigraphy, Strike 065°-075° Dip 75°N. Slickensided north wall. Horizontal and vertical boudins. Ore zones plunge 10-20°W. Strike and dip faults show calcite breccia. Minor ladder vein development. Quartz vein thickness 0-3 metres in core of grey zones 1-10 metres in thickness.	Crack and seal vein. Mainly white quartz with stylolites of carbonaceous material, chlorite, brown tourmaline and sericitic material sub-parallel to contacts. 1-5% fine-coarse pyrite. Trace sphalerite, chalcopyrite, scheelite, and hydromuscovite. Calcite and other carbonates adjacent to faults.
14	Crosscuts stratigraphy. Strike 060-090°. Dip 10-30°S in fold noses otherwise 70°S. Ore zones plunge 10-20°W and are cut by numerous reverse faults. Quartz vein thickness 0-4 metres.	Crack and seal white quartz vein. Stylolites and pyrite as in 16-vein. Local 0.5% sphalerite and/or chalcopyrite.
13-11	Crosscuts stratigraphy. Strike 020°. Dip 20-80°E, mainly 70°E. Branching network. Ore zone plunges 25°N-0.2 metre thick ladder veins. Reverse faults truncate veins.	Smokey grey ladder vein. Cut by barren white quartz "rungs". 1-5% wisps and clots of brown tourmaline, 1-5% fine pyrite. Local 1% scheelite. Calcite adjacent to faults.
10-18	Sub-parallel to stratigraphy. 5-15% thin quartz stringers cut by 5% oblique angle thin quartz stringers.	Thin white-quartz stringers, local bright green chlorite and/or carbonate. 2-10% fine-coarse pyrite.
7	Crosscuts stratigraphy. 0-1.5 metre thick quartz vein strikes 090°-120° and dips 10-40°N. Cut by numerous subvertical faults.	Similar to 13-11 vein.

TABLE FHOYLE4: Simplified alteration mineralogy and qualitative gains and losses for some of the alteration types recognized at the Falconbridge Hoyle Pond Mine (after Rye 1987).

	MINERALOGY	CHEMISTRY	
Host Tholeiite	chlorite + clinozoisite + actinolite + quartz + dolomite + calcite ± sphene ± rutile	Gain:	Si
		Loss:	Ca, K
		Variable:	Mg, Na, Fe, Ti, P
Outer Grey Zone	ankerite + low Fe chlorite + paragonite + calcite + quartz + carbon ± albite	Gain:	Ca, Na, Fe
		Loss:	Si, Mg, Ti
		Variable:	K
Inner Grey Zone	Fe dolomite + calcite + high Fe chlorite + muscovite + carbon + quartz ± paragonite ± rutile	Gain:	Si, Ca, K, Fe
		Loss:	Na, Mg, P
		Variable:	Ti

up to 0.5 metres in thickness, occurs parallel to the veins. This halo consists of two to five percent disseminated euhedral pyrite, which ranges from 0.5 to two centimetres in grain size. Mapping suggests that following "14-", "13-", and "11-veins" along plunge leads to an intersection with "16-vein". The "7-vein" is more likely a tensional feature related to the contact between the ultramafic and Hoyle Pond magnesium-rich tholeiite units. Recent drilling south of the ultramafic komatiites, in the Owl Creek magnesium-rich tholeiites, has shown interesting gold values associated with thin quartz stringers in ankerite-carbonate-fuchsite-pyrite altered rock.

The ultramafic and basaltic komatiite rocks are brittle and susceptible to fracturing during deformation as a result of carbonatization (i.e., ground preparation). Komatiites at depth, and along the Destor-Porcupine Fault, may have been a possible source of gold as well (Pyke 1976; Viljoen 1984). Hydrothermal transport of gold by a thio-complex is favoured.

8.5.7. Temporal Constraints

Colvine et al. (1988) provide an excellent summary of deformation and temporal relations. Strain analyses of gold deposits have demonstrated that the present sites of mineralization represent zones of dilation produced by shear deformation (see also many excellent references in Geology of Canadian Ore Deposits, CIM Jubilee Volume, 1948). Structural studies also indicate that the shear fabric is superimposed upon fabrics produced by folding or tilting. The youngest greenstone lithologies that host gold deposits (older metavolcanic rocks and the Timiskaming-type metasedimentary rocks and associated intrusions) record only the younger (shear) fabrics. Thus, mineralization was synchronous with, or post-dated, shearing.

8.5.8. Tour Guide

Because of the active mining in the Hoyle Pond Mine, a specific tour itinerary will be made available immediately before the mine visit.

8.5.9. Acknowledgements

The Hoyle Pond Mine has matured from a raw Texasgulf prospect in 1969 to a Falconbridge Gold Corporation Mine which produced 55,000 ounces of gold in 1989. Along the way, the following people have participated in this success story:

1) 1969- V.N. Kelly, R. Ginn - Drilling;

2) 1979-1981- J. Derweduwen, M. Downes, D. Mullen, D. Hodges, R. Bald, D. Last, D. Londry, W. Gasteiger, and G. McVeigh - drilling, geology, geophysics, and geochemistry;

3) 1981-1986- J. Derweduwen, P. Karelse, D. Miller, K. Polk, Project Development Group;

4) S. Halladay, G. McTaggart, D. Scott - feasibility;

1984-Present- D. Caron, P. Coad, R. Labine, M. Forestell, M. Jerome, J. Pattison - Production.

Bell Creek and Marlhill Mine Area

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The Bell Creek and Marlhill Gold Mines are located in the southwest corner of Hoyle Township, and are owned and operated by CANAMAX Resources Incorporated. The Bell Creek Mine, which entered full production on January 1 1987, has produced 306,244 tonnes of ore grading 6.76 g/tonne, to the end of 1989. Initial production was from the North "A" Zone, a single vein system which lies roughly 200 metres north of the main shaft. The "Bell Creek West" is a second important zone which occurs 50 metres west of the shaft. Mineralization in this zone consists of disseminated sulphide within carbonatized rock. Quartz veins are minor. Development and production from this zone are expected to begin in 1990. The third major economic zone occurs at the Marlhill Mine, where gold mineralization occurs as quartz veins. This zone is located one kilometre north of the head frame and is currently serviced by a ramp down to the 150 metre level. Production from three major quartz vein systems at Marlhill commenced in January 1989.

8.6.1. Regional Geological Setting

The mineralization at Bell Creek and Marlhill Mines occurs within the northern part of the Tisdale assemblage (Fig. Bell1). Historically, the ultramafic komatiitic and iron- and magnesium-rich, tholeiitic basalt flows which characterize this part of the assemblage, and which serve as hosts to the gold mineralization, have been referred to as lower "Tisdale Group" (Pyke 1982).

8.6.2. Lithologies

8.6.2.1. Unit 1 - Ultramafic Metavolcanic Rocks

Dark green, medium to fine-grained ultramafic rocks form the south boundary of the mine sequence. This lens-shaped unit forms pods 100 to 200 metres in thickness, which have locally been affected by zones of intense ankerite-fuchsite alteration. Fragmental basalt flows occur within and along the north contact of the ultramafic unit and form the host rock to the Bell Creek gold horizon. Barren to weakly auriferous, quartz-carbonate veins occur throughout the unit.

8.6.2.2. Unit 2 - Basaltic Metavolcanic Rocks

This east-striking, steeply dipping sequence consists of amygdaloidal, variolitic, and massive, leucoxene-bearing basalt flows, minor tuff and lapilli tuff (Unit 2A), and minor interflow metasediments (Unit 2B). The sequence is more than 1 kilometre in thickness. The massive flows are host to all of the economic auriferous, quartz vein mineralization. The lack of distinctive marker horizons within the flows makes detailed structural observation difficult.

A sub-unit 2A, interlayered with the basalt flows, consists of green to greenish-yellow ash-tuff and lapilli-tuff and is generally less than 20 metres in thickness. The tuff units contain minor amounts of carbonaceous material, especially where finer grained. The fragmental units occur in proximity to the North "A" Zone and may represent either pyroclastic units or structurally disturbed and altered basalts.

Sub-unit 2B consists mainly of finely layered, graphitic argillite interflow metasediments or ash tuffs. These units are less than 10 metres in thickness. Between the ultramafic-basalt contact (Unit 1-2) and the main, Bell Creek graphite marker 400 metres to the north, the interflow metasedimentary units occur repetitively at 50 to 100 metre spacings. North of the Bell Creek graphite marker, interflow sediments are rare. Gold mineralization occurs within graphitic argillite in the North "B" Zone.

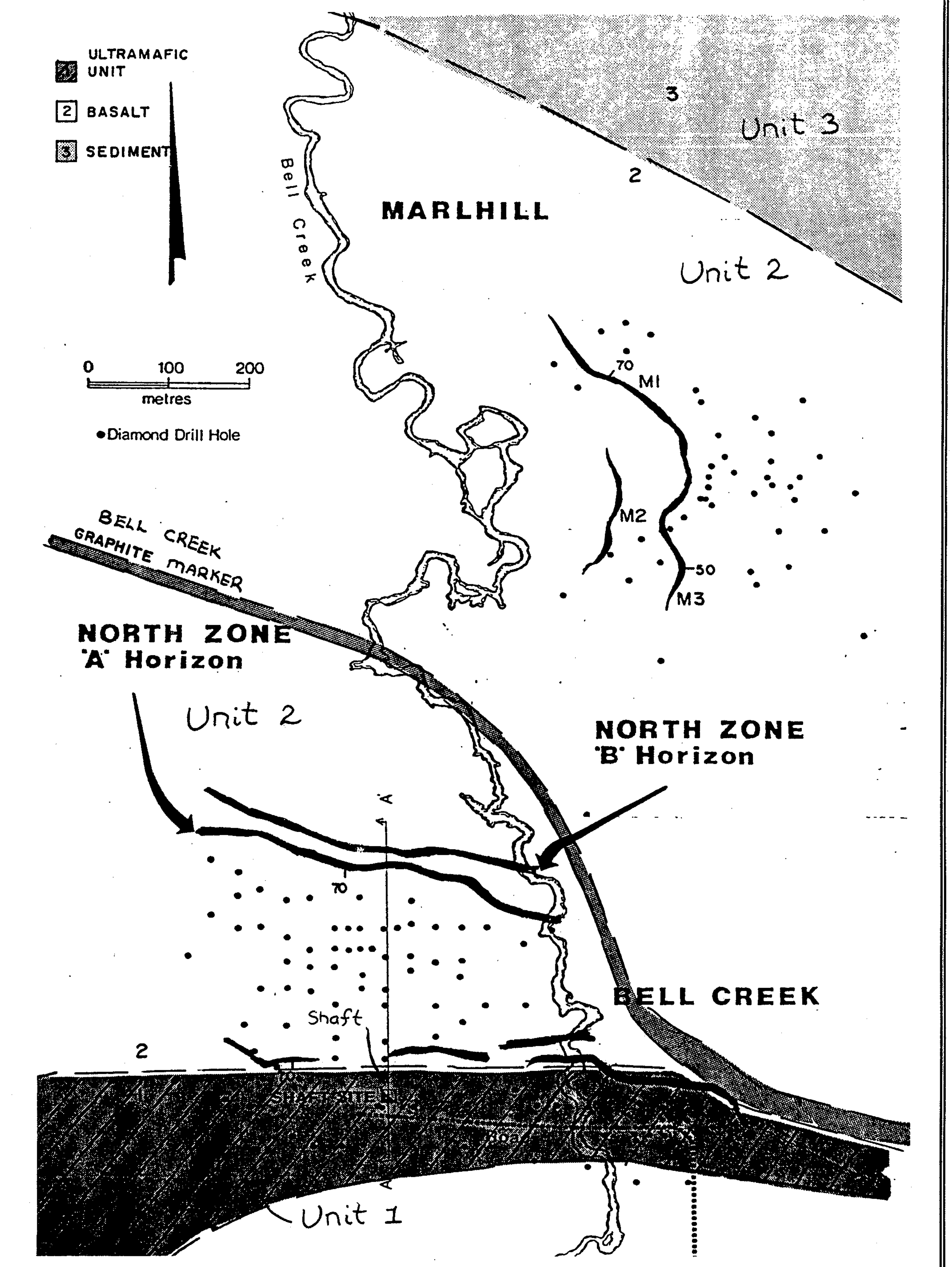

Figure BELL1: Location of mineralized zones at the Bell Creek, and Marlhill Mines.

8.6.2.3. Unit 3 - Metasediments

This southeast striking metasedimentary sequence consists of steeply dipping, fine- to medium-grained wacke - mudstone couples, in which defined graded bedding is preserved. It lies to the northeast of and defines the north boundary to the Marlhill Zone (Fig. Bell1). The sequence is separated from Units 1 and 2, metavolcanic rocks to the southwest by a second, laterally continuous, graphitic unit. It is not known if economic gold mineralization occurs within these metasediments because they have only been probed by widely spaced drill holes. However, within the metasediments, diffuse zones of quartz stringers have been observed, some of which are associated with erratic, but anomalous gold values up to one g/tonne.

For 200 metres northeast of the contact between the metavolcanic and metasedimentary rocks, the metasediments face north. Farther to the north and northeast, the metasediments face south and hence appear to have been folded.

8.6.2.4. Unit 4 - Diabase

All rock types are cut by north-striking, diabase dikes of the Matachewan swarm (Fahrig and West 1986). Thin, carbonatized lamprophyre dikes also cut the Marlhill Mine metavolcanic rocks; however, crosscutting relationships between these dikes and auriferous zones have not been established.

8.6.3. Structure

The structural and stratigraphic setting of the Bell Creek-Marlhill ore bodies is indicated in figure Bell1. An east-striking (080o to 110o), steeply dipping, penetrative foliation is developed is all rocks in the mine area. In the Marlhill Mine area, minor folds and mineral lineations plunge 60o to the southeast. Veins in the Bell Creek Zone North "A" and "B" zones and the new "5850-vein" structure, all lie south of the Bell Creek graphite marker and have strikes parallel to the east-striking foliation. These auriferous, "strike-type" vein zones may be directly related to shear zones, given that moderate to strong shearing adjoins the Bell West and North "A" horizons. However, these shears cannot be confirmed by displacement of early geological formations.

The trace of the North Tisdale Anticline (Ferguson et al. 1968; Pyke et al. 1971) is inferred to pass through the Bell Creek Mine Area and may account for some of the folds observed on the mine property. Late stage brittle deformation occurs along a series of flat faults at the Marlhill and Bell Creek Mines. Displacement of the ore veins varies from a few centimetres to two metres on these flat faults and is accompanied by minor drag folding. Calcite and chlorite coat the flat fractures, which also form planes of weakness in the metavolcanic host rocks.

8.6.4. Mineralization

8.6.4.1. Bell Creek Zone

The Bell Creek mineralized zone is a "sulphide - flow ore-type", which is preferentially developed on or near the contact between the unit 1 ultramafic rocks and unit 2A fragmental basalts. The fragmental basalt unit is the preferred host. Mineralization consists of two to ten percent pyrite and accessory arsenopyrite (typically 100-500 ppm As in ore), pyrrhotite, and chalcopyrite, although minor quartz veins are is present. Roughly 90 percent of the gold is associated with the disseminated sulphides, which occur within highly altered quartz-carbonate-sericite-sulphide zones up to 0.5 to seven metres in width. Erratic gold values occur in the quartz veinlets. These veinlets cut the altered rocks at all angles, especially in the hanging wall ultramafic unit. Non-auriferous veins surrounding the sulphide-carbonate gold zone generally occur as gash or en-echelon type structures.

The ore-grade mineralization occurs in pods or lenses not more than 100 metres in strike length and 200 metres vertical extent. The ore lenses appear to plunge steeply to the east. Multiple zones have been located along a strike length of one kilometre at or near the favourable Unit 1 - Unit 2A (ultramafic-basalt) contact. Active carbon occurs in some of the mineralized pods in the form of sheared graphitic interflow sediments and mining is not planned in these areas due to the deleterious affects of the carbon to the recovery of gold.

8.6.4.2. North Zone

The North Zone consists of two sub-parallel, west-northwest-striking mineralized bands termed the "A", in the south, and "B" in the north. The two zones are roughly 25 metres apart and dip at 70° to the south.

The mineralized portion of the "A" horizon consists of a quartz marker vein ten centimetres to two metres in width, and averages only 0.5 metres in width. The marker vein parallels the regional schistosity and crosscuts green, fragmental tuff, variolitic basalt, leucoxene-bearing basalt, and narrow beds of graphitic argillite. Bright green hydromuscovite occurs as fracture and slip coatings in the vein and platy, visible gold occurs with the mica. Tourmaline is fairly wide spread within the vein. The "A" zone contains the best gold values, averaging six to ten g/tonne over widths of two to ten metres. Surrounding the central quartz vein is a grey to buff coloured altered zone, which contains five to fifteen percent pyrite and pyrrhotite with accessory chalcopyrite and arsenopyrite. Up to 30 percent of the gold in the North "A" vein system occurs within the alteration halo, in discrete sulphide zones, in vein-brecciated wall rock zones which extend up to five metres from the margin of the core vein.

The "A" zone has been developed along a strike length of 250 metres, and from surface to the 240 metre level. An internal ramp system is currently underway to access ore at the 300 metre level. Deep drilling has intersected the ore zone at a depth of 400 metres. Current mining is entirely by shrinkage stoping. Long-hole stopes were common until early 1989, when it was realized that a weak hanging wall resulted in excessive dilution.

Gold mineralization in the North "B" zone has been noted in drill holes over a strike length of 100 metres. As in the "A" zone, gold occurs with sulphides in a quartz vein and in a quartz veinlet halo in the adjacent wall rock. Carbonate alteration of the wall rock is only weakly developed. Abundant graphite occurs in the argillaceous host rocks. This zone has an average grade of 2.8 g/tonne across 4.4 metres and is considered to be sub-economic at this time.

8.6.4.3. Marlhill Mine Area

The Marlhill vein system is located 600 metres northeast of the North "A" zone, to which it is similar. The Marlhill veins strike north to northwest and dip to the northeast. Some of these quartz veins have been folded and this complex vein deformation history may have contributed to the localization of gold within individual vein systems. Generally, mineralization consists of a 0.1 to three metre wide central quartz vein, which contains two to five percent fine-grained pyrite, arsenopyrite, and rarely visible gold. Gold occurs as plates on the surfaces of the sulphide minerals, but shows a preference for arsenopyrite. Significant amounts of brown tourmaline (dravite) occur in all veins. Where white mica and sulphides commonly occur on slips and fractures within the vein, gold tenor generally attains economic values. A sericite-sulphide halo extends up to one metre from the vein. Only about 10 to 20 percent of the gold occurs associated with this wall rock sulphide. Coarse to medium grained cubic pyrite extends farther away from the vein margin, into the host mafic metavolcanic rocks.

Two types of quartz vein systems are observed:

1) long, linear, southeast-striking veins (M1 system) which cut the regional foliation at roughly 45° and which show local, intense folding parallel to a 080° axial planar surface; and

2) shorter and thicker quartz vein systems (M2 and M3 veins) which cut the foliation at 60° to 90° degrees, but have been folded parallel to the 080° foliation.

Of the three Marlhill veins currently under exploitation, the most significant is the M1. It has been traced for 250 metres along strike, and to a depth of 250 metres. The M2 and M3 are parallel, north striking veins which have shorter strike lengths and appear to form economic lenses in saddle reef type structures. In both the M2 and M3 vein systems, the strongest gold mineralization occurs within a zone, 75 to 100 metres long along strike, which is centred upon a fold axis. This fold plunges 60° to the southeast and has an axial plane which strikes east.

Foliation-parallel quartz and quartz-tourmaline "strike" veins also occur. These veins occur within 080° zones of intense foliation (ductile shear zones?), and dip 80° south. The "strike" veins and associated cubic pyrite are barren of significant gold values. Locally the "strike" veins cut the M1, M2, and M3 veins.

8.6.5. Rock Alteration

Alteration patterns are similar at all three of the gold zones in the Bell Creek - Marlhill Mines. Chlorite and sericite-carbonate zones are the two main alteration types present.

8.6.5.1. Chlorite-rich Assemblage

Chloritic alteration is widespread. A weak chlorite alteration is associated with the axial planer cleavage in all of the mafic and ultramafic host rocks. In the basaltic rocks, purple-white coloured leucoxene occurs as distinctive, fine-grained, skeletal crystals up to two millimetres in length. Leucoxene may locally form up to five percent of the rock.

8.6.5.2. Sericite-carbonate Assemblage

This alteration assemblage is generally developed adjacent to an auriferous vein, but may extend up to 20 metres from a vein margin. The widest zones of sericite-carbonate alteration occur within the ultramafic rocks (Unit 1), where alteration extends well beyond the limits of mineralization. The sericite alteration typically forms a 20 to 30 metre wide halo surrounding the Bell Creek sulphide-hosted gold zone, where fuchsite surrounds zones of intense quartz-ankerite veining and fractures.

Beige to grey coloured alteration zones, consisting of sericite, iron-carbonate, and silica, surround the main quartz vein structures. A visible halo, one to five metres in width, is common in the North Zone and a more restricted alteration halo, 0.1 to one metre in width, surrounds the Marlhill veins. The carbonate in this visible halo is generally a grey ankeritic variety or pale, buff-coloured dolomite. Albite is noted in thin sections with some coarser crystals observed on the vein margins.

8.6.6. Tour Guide

Due to the dynamic state of underground mining of these deposits, the precise tour will not be available until shortly before the tour group arrival.

9. DEPOSITIONAL MODELS

Based on largely empirical data, presented during the course of the field trip, a summary of the salient aspects of the deposit types and their geological settings is given. These descriptive characteristics of the Timmins' area deposits are then briefly examined in the context of the "popular" depositional models that describe each deposit type considered on this tour. This permits evaluation of the degree to which the models provide a rational and consistent explanation of the deposit characteristics.

In this guide, a depositional model is distinguished from a genetic model in that it represents a synthesis of empirical data drawn from many deposits, with a minimum of genetic interpretation. A deliberate attempt has been made to minimize the introduction of genetic models and interpretations as they relate to fluid origin and metal sources.

Towards a Genetic Model For Komatiite-related Nickel Sulphide Deposits

A.H. Green[1] and D. MacEachern[2]

Extremely detailed and valuable studies of these deposits have been conducted in the Kambalda to Mt. Keith area of Western Australia (Ross and Hopkins 1975; Lesher 1988). In particular, during the 1980's studies of these deposits continued even when the price of nickel fell very low and mining reached a minimum. These studies provide a large body of evidence but additional observations, from other locations, need to be added to this base to validate the model as being global rather than of local application. Despite great progress, there is still considerable controversy and a number of theories concerning their formation remain unresolved and unproven. For example, the iron-sulphide-bearing metasediments are believed to be a major source of sulfur (Arndt and Jenner 1986; McNaughton et al. 1988) for the magmatic system. However, in many Archean sequences, both the nickel sulphides and the adjacent iron-sulphide-bearing metasediments have near-magmatic sulphur isotope values (Seccombe et al. 1981; Lambert et al. 1978). Hence, in these cases it is not possible to test the sulphur assimilation hypothesis using the sulphur isotopic data. In the Timmins area, sulphur isotopic values in the deposits and the nearby metasediments range widely (Green and Naldrett 1981; Eckstrand, Geologist, Geological Survey of Canada, personal communication, 1990), including non-magmatic values. A number of features are observable in the nickel deposits of the Timmins area. These deserve further study and could contribute to a significantly better understanding of this deposit type.

The following is a partial list of features of the deposits that must be explained by any genetic model:

1) they occur in clusters;

2) they appear to occur on very specific single stratigraphic horizons;

3) the deposits constitute a restricted exploration target within this planar target cluster, apparently related to very MgO-rich komatiites;

4) the nickel sulphides grade laterally to iron-sulphide-bearing metasediments;

5) at Dundonald, Hart, Redstone and Langmuir #2, nickel sulphide mineralization also occurs within the metavolcanic footwall, but is traceable directly back out to the main footwall or ore horizon;

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[2] Falconbridge Limited (Exploration), 571 Moneta Ave., Box 1140, Timmins, Ontario. P4N 7H9

6) alteration, whether replacement by serpentinite or talc-carbonate, is quite variable and apparently unrelated to the major ore zones;

7) economic concentrations of nickel sulphide mineralization are not confined to zones of penetrative deformation;

8) except where remobilization can be inferred, the extent of the higher grade, nickel sulphide zones is restricted to beneath, or at the base of, the very MgO-rich (>40 weight percent) flows;

9) sulphur isotope and Se/S ratios of sulphide minerals clearly show that the sulphides cannot have an entirely magmatic source of sulphur. Furthermore, the sulphur in the adjacent metasedimentary rocks have similar values or values consistent with a mixing of sedimentary and magmatic sulphur;

10) PGE-values are variable -e.g., Alexo PGE-values are different from those of the Shaw Dome deposits.

9.1.1. Current Ideas

The genetic model that best explains these deposits is that developed by Lesher in several articles, including Lesher et al. (1984). They envisage voluminous eruption of komatiites into rifting greenstone belts, forming large, channelized lava flows. Sulphidic footwall rocks are assimilated in variable amounts during various stages of komatiite emplacement. Flows assimilating large amounts of sulphide-rich footwall rocks should achieve sulphide saturation early, and segregate sulphides rapidly, to form the classical sequence of massive, matrix and disseminated sulphides at the base of the first flow. With smaller amounts of assimilation, flows should form only disseminated nickel sulphides.

Thermal erosion should be significant where the footwall consists of metasedimentary or felsic metavolcanic rocks, in contrast to tholeiitic basalts or komatiitic rocks. Thermal erosion and assimilation should be greatest below the main channel, giving sharp contacts with the footwall, although some flanking mineralization would be possible. Sulphides should accumulate in topographic lows. Since the sulphide segregations would have been above their liquidus of 1220 to 1160° C, while the komatiite magma was molten (solidus about 1200° C), the low viscosity sulphides could have easily been remobilized after segregation. According to this model, lava channels and sulphidic metasediments are essential components. Without both, the deposits could not form. This model seems to explain most of the features of the Timmins area deposits, and why some other areas around Timmins host no known deposits.

VMS Depositional Model

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Volcanic-associated massive sulphide (VMS) deposits belong to the larger class of concordant massive sulphide deposits that includes all massive or semi-massive sulphide deposits that formed by the discharge of hydrothermal solutions beneath and onto the seafloor (Gilmour 1976; Sangster 1972; Franklin et al. 1981; Lydon 1984). The idealized deposit consists of a concordant lens of massive sulphides, composed

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of 60 percent or more sulphide minerals, which is stratigraphically underlain by a discordant or stringer zone of vein sulphide minerals, contained in a pipe of hydrothermally altered rock (Sangster 1972; Sangster and Scott 1976; Lydon 1984). The upper contact of the massive sulphide lens is usually in sharp contact with the hanging wall rocks, but the lower contact is usually gradational into the stringer zone. The stringer zone is interpreted to have been the locus of hydrothermal fluid discharge (Sangster 1972).

Within the Superior Province, these deposits occur preferentially in multicyclic, bimodal mafic-felsic metavolcanic sequences. However, within a given area, not all mafic-felsic sequences of comparable age are mineralized. Where present within a mafic-felsic sequence, VMS mineralization tends to occur in the middle and upper stratigraphic, subaqueous units.

There exists a classical concept that VMS deposits occur associated with rhyolite. As demonstrated by the mineralization at the Canadian Jamieson and Potter Mines, some mineralization also occurs associated with tholeiitic basaltic rocks. Even in the classical Noranda camp, there are deposits, such as the Corbet (Knuckey and Watkins 1982), which occur associated with mafic metavolcanic sequences. Therefore, the presence of rhyolite is an important spatial associate at a camp scale, but rhyolite need not occur in the immediate footwall of a massive sulphide deposit (Franklin 1986).

Felsic metavolcanic footwall rocks associated with many VMS deposits in the Superior Province are chemically distinctive, characterized by elevated REE abundances and a flat REE pattern with a marked negative Eu anomaly (e.g., Thurston 1981; Lesher et al. 1986). Such felsic rocks occur associated with VMS deposits at Noranda (Cycle III; Ujike and Goodwin 1988), the deposits in the Mattagami Lake, Kidd Creek and Kamiskotia areas (Lesher et al. 1986), in the Abitibi greenstone belt, and at the South Bay Mine, in the Uchi Subprovince (Thurston 1981).

Some VMS deposits occur within sequences of intermediate to felsic metavolcanic rock which are interpreted to have accumulated within caldera structures, and formed following a period of subaqueous, resurgent volcanism (e.g., Thurston 1986; Morton and Franklin 1987). A large, subvolcanic intrusion commonly occurs stratigraphically below the deposits or camp, in the core of such inferred cauldron structures (e.g., Flavrian trondhjemite- Noranda; Beidelman Bay trondhjemite- Sturgeon Lake; Kamiskotia Gabbroic Complex- Kamiskotia; Bell River Gabbro sills- Mattagami Lake). These subvolcanic intrusions are interpreted to be the source of the volcanic material and likely also supplied heat to drive the convective hydrothermal system (e.g., Franklin et al. 1981). They may have been the source of metal-rich hydrothermal fluids (Campbell et al. 1981).

Based partly on metal ratios, characteristics of the depositional environment, and alteration habit, VMS deposits in the Superior Province have been subdivided into Cu-Zn or Noranda-type, and Zn-Cu-(Pb), or Mattabi-type subgroups (Morton and Franklin 1987).

9.2.1. Noranda-type Depositional Model

The Noranda-type deposits lie close to their exhalative vents, characterized by distinctly zoned alteration pipes. Chemically, the pipes are characterized by cores which have been depleted in sodium and calcium and enriched in magnesium. Enveloping this core is a zone which has been enriched in potassium (e.g., Franklin et al. 1981).

These chemical characteristics are reflected in the distinctive mineralogy of these pipes, depending on the metamorphic grade. Where metamorphosed to sub-amphibolite facies, the alteration pipes in the Noranda camp are zoned from a magnesium-rich chlorite (magnesium-ripidolite) + quartz inner assemblage to an outer, sericite + quartz assemblage with or without chlorite (Riverin and Hodgson 1980; Franklin et al. 1981; Franklin 1986). Talc is common beneath the Mattagami Lake deposit (Costa et al. 1983). Where metamorphosed to higher metamorphic grades, the inner zones may consist of anthophyllite + cordierite, with varying amounts of iron-rich chlorite, talc, phlogopite, and sillimanite or andalusite and the outer zone may consist of quartz, sodium-rich sericite, staurolite and lesser sillimanite (Morton and Franklin 1987).

Beneath some of the Cu-Zn deposits, a lower semi-conformable style of alteration is described, which generally occurs as deep as three kilometres below the paleo-sea floor on which the sulphides were precipitated (MacGeehan and MacLean 1980; Gibson et al. 1983). This alteration consists of both silicified and spilitized (epidote and quartz with or without albite, actinolite, and magnesium-chlorite) rock. These lower semi-conformable zones are laterally extensive (kilometres) and attain a thickness up to 100's of metres (Morton and Franklin 1987).

Primary permeability, such as synvolcanic faults, controlled the emplacement and localization of extrusive rhyolite domes and associated synvolcanic intrusions (e.g., quartz-feldspar porphyritic dikes and domes in Noranda). These structures apparently also served to channelize hydrothermal fluids (Knuckey et al. 1982).

9.2.2. Mattabi-type Depositional Model

Alteration pipes are less well defined or not as easily recognized beneath the Zn-Cu-(Pb) Mattabi-type deposits. Siderite, chloritoid, sodium-rich sericite, iron-chlorite (iron-ripidolite or chamosite), andalusite, and kyanite may occur. Silicified rock can occur immediately below the deposits. The lower semi-conformable alteration associated with the Zn-Cu-(Pb) VMS deposits consists of a sericite-quartz-calcite or dolomite type and an iron-rich chlorite-iron carbonate-and/or chloritoid-andalusite-kyanite assemblages (Groves 1984; Morton 1984; Morton and Franklin 1987). This lower semi-conformable alteration zone may extend closer to the paleo-sea floor on which the sulphides precipitated, than those recognized in the Noranda model depositional environment.

9.2.3. Empirical Characteristics - Kamiskotia Area

The following empirical relationships, observed in the Kamiskotia area, are consistent with the existing depositional models:

1) the stratigraphic sequence in which the VMS deposits occur is characterized by bimodal volcanism;

2) the Kamiskotia gabbroic complex constitutes a large, subvolcanic intrusion which supplied heat and perhaps metals to the hydrothermal system (Lesher et al. 1986). Such intrusions are inferred to be an important component of the geological setting of VMS deposits in many camps;

3) the felsic metavolcanic rocks are characterized by a distinctive geochemistry, which may indicate that they evolved within and were derived from, high-level, subvolcanic, zoned mafic-felsic magma chambers (Lesher et al. 1986);

4) the felsic metavolcanic rocks are an important component of the mineralized environments, but they aren't always the host to mineralization. For example, mineralization at the Genex, Jameland and Kam-Kotia deposits occurs within mafic metavolcanic rocks. At Canadian Jamieson, mineralization occurs within mafic fragmental rocks, stratigraphically below a felsic metavolcanic sequence;

5) at a deposit-scale, hydrothermal fluids were localized along zones of porosity and permeability. At the Genex Mine, growth faults were important fluid conduits. At Canadian Jamieson, mafic fragmental rocks served as the hydrothermal aquifer;

6) replacement of host rocks by iron-bearing carbonate, associated with the mineralization, is recognized only at the Canadian Jamieson Mine, the deposit which is closest to significant accumulations of subaerial metavolcanic rocks. The presence of hydrothermal ferroan carbonate is a characteristic of the Mattabi-type model;

Certain characteristics of the depositional environment in the Kamiskotia area are consistent with the general characteristics of the Mattabi-type depositional and genetic model. The presence of subaerial metavolcanic rocks in the Kamiskotia area indicates that the volcanic succession did shoal-upward. This is consistent with the voluminous amount of fragmental mafic and felsic metavolcanic rock in the depositional environment. Although zones of alteration are recognized, more dispersed hydrothermal fluid discharge appears to have been favoured. This style of fluid discharge did not favour the development of distinctive pipe-shaped zones of alteration. The local replacement of metavolcanic rock by ferroan carbonate is also characteristic of the Mattabi-type regime and may indicate CO_2 effervesence from the hydrothermal fluid, under shallower water conditions (e.g., Morton and Franklin 1987).

There are some characteristics of the Kamiskotia area depositional setting which are not consistent with either of the depositional models. Only about 200 metres of volcanic stratigraphy remains beneath the deposits in the Kamiskotia area and the Kamiskotia gabbroic complex. The presence of a lower semi-conformable alteration has not been confirmed in this thin footwall metavolcanic sequence. However, an apparently stratiform zone of marked sodium depletion and potassium enrichment exists stratigraphically above the VMS deposits (Middleton 1975). The genetic relationship between this alteration zone and the hydrothermal system from which the Kamiskotia VMS deposits formed remains unclear.

Icelandite sills and flows are usually present in the stratigraphic sequence which hosts the orebodies, and elsewhere in the Kidd-Munro and Kamiskotia assemblages. Although the presence of this rock type is not, by itself, an unusual feature, it represents a fractionated component of the rock suite, consisting of tholeiitic basalt, icelandite, and high-silica rhyolite. By analogy with Phanerozoic tectonic settings, the presence of this chemically distinctive suite provides some insight into the possible rift-type tectonic setting in which these metavolcanic rocks, and their associated VMS deposits, evolved.

9.2.4. Empirical Characteristics Kidd Creek Area

The following empirical relationships, observed in the Kidd Creek area, are consistent with the existing depositional models:

1) the deposit occurs at the top of a felsic metavolcanic sequence, at the contact between subaqueous felsic and overlying, mafic metavolcanic rocks;

2) there is no indication of the presence of a thick (>300 metres) accumulation of felsic metavolcanic rock in the Kidd Creek mine area and little evidence exists to attribute the felsic volcanism to the development of a caldron structure;

3) the rhyolite unit immediately beneath the Kidd Creek deposit appears to be locally thickened (300 metres), and thins to less than 100 metres away from the deposit. The geometry of this thickened sequence (elongate and tabular down dip, but much thinner away from the deposit) may indicate that the eruptive centre for the felsic unit was controlled by a planar structural feature. Such synvolcanic structures control the distribution of the porphyry-domes in the Noranda camp (Knuckey et al. 1982). However, the metavolcanic rocks in the Kidd Creek mine area have undergone post-mineralization deformation which may account for some or all of the stratigraphic thickening.

4) primary, high-silica rhyolites (up to 78 weight percent SiO_2) are present in the mine sequence (e.g., Lesher et al. 1986). Rhyolites having higher SiO_2 abundances have had silica added during hydrothermal alteration;

5) the felsic metavolcanic sequence in the mine area contains a significant amount of autoclastic and pyroclastic rhyolite breccia; this breccia may be attributed to much explosive volcanic activity, suggestive of a shallower water eruptive regime, a gaseous magma, or brecciation in response to increased topography in the immediate mine area;

6) the Kidd Creek mine area is lithologically diverse. This is consistent with the localization of much igneous activity in this area, a consequence of which would have been a higher heat budget in the crust. This may have enhanced the generation of synvolcanic fracture systems and the initiation of a convective, hydrothermal system;

7) the existence of a classical alteration pipe beneath the deposit is debated. Either it is not preserved, was never present, or is not recognized in the present configuration. A discordant zone of intense silica replacement, flanked by an outer zone of chloritization, accompanied the chalcopyrite stringer zone in the open pit and upper levels of the mine (down to the 1200 level) and may represent such an alteration pipe;

8) the presently documented extent of the stringer and chlorite alteration zone is coincident with the extent of the massive sulphide deposit and extends from surface to the lowest level for which reserves are

calculated (5600 level). Channelized hydrothermal fluid discharge, coincident with the extent of the sulphide mass, may reflect the influence of a planar, graben-like, synvolcanic structure beneath the deposit;

9) metal zoning within the deposit is defined by the enrichment of chalcopyrite in the stringer zone and the base of the massive sulphide deposit, and the enrichment of sphalerite, pyrite, and galena towards the top of the deposit;

10) ferroan carbonate occurs in the mineralized system as carbonate bands and masses within sphalerite-pyrite ores and as fractures in the stringer zone. Although consistent with the Mattabi-type model, the timing of the carbonate-filled fractures is not known;

11) the change from iron-rich chlorite in the core of the stringer and alteration zone, to magnesium-rich chlorite outside the stringer zone at Kidd Creek (Slack and Coad 1989), is a characteristic of the Mattabi-type model (Morton and Franklin 1987).

Certain characteristics of the Kidd Creek depositional environment are consistent with both the Noranda- and Mattabi-type depositional models. The presence of significant amounts of autobrecciated and pyroclastic rhyolite in the mine sequence is consistent with a shallower water eruptive regime, on a seafloor which had some topographic relief. Unlike the Kamiskotia area, no subaerial metavolcanic rocks have been documented in the Kidd Creek area. The presence of secondary ferroan carbonate is also consistent with the Mattabi-type model, although some of this carbonate may have been introduced long after synvolcanic hydrothermal activity (Schandl and Davis 1989). Hence, until the timing of the carbonate varieties is documented systematically, the presence of ferroan carbonate in the Kidd Creek and Kamiskotia depositional environments cannot be cited as a characteristic that uniquely supports either of the genetic models.

The inferred locus of hydrothermal fluid discharge, coincident with the prolate extent of the deposit, is consistent with channelization of the fluid along a synvolcanic structure. This inferred synvolcanic structure may also have acted as an eruptive conduit, along which the thickest accumulation of felsic metavolcanic rock accumulated. Such structural controls on the localization of magmatism and hydrothermal activity are well documented in the Noranda area (e.g., Knuckey et al. 1982).

An important geological anomaly of the Kidd Creek area is the apparent absence of a subvolcanic intrusion. Such an intrusion may be manifest as the poorly documented peridotite complex which occurs in the footwall of the deposit. Alternatively, this complex may represent a sequence of extrusive komatiitic flows. Subvolcanic magma chambers in other VMS camps can lie up to several kilometres stratigraphically beneath the mineralized horizon. Two porphyritic granitoid stocks, approximately one kilometre in diameter, occur three kilometres east and four kilometres northeast of the Kidd Creek mine, in Wark and Prosser townships respectively. The possible spatial and genetic relationships of these stocks to the metavolcanic rocks and mineralization in the Kidd Creek mine area is difficult to assess due to the scarcity of outcrop and structural complexity. Similarly, the structural complexity and poor bedrock exposure may explain why a lower semi-conformable alteration zone has not been recognized in the Kidd Creek area.

9.2.5. Empirical Characteristics Potter Mine Area

The following empirical relationships, observed in the Potter Mine area, are consistent with the existing depositional models:

1) the mineralization overlies the junction of a large, layered, tholeiitic intrusion (Centre Hill Complex) and a komatiitic lava lake. The intrusion may have breached the surface, and can be interpreted as a synvolcanic, high-level magma chamber;

2) the contact between the lava lake and the Centre Hill Complex is also a zone of shearing. The lack of significant displacement of overlying units suggests that this may have been a synvolcanic fault, through which hydrothermal fluids could have been channelized. Alternatively, this could have been a zone of predominantly dip slip shearing;

3) chlorite replacement of the hyaloclastite accompanies zones which are sulphide-bearing. A possible chlorite alteration zone, with associated stringer mineralization, occurs beneath the deposit in the area of the possible synvolcanic fault;

4) carbonate also occurs as a hydrothermal mineral in the hyaloclastite matrix, but the timing of carbonate introduction (e.g., sea floor diagenesis, synvolcanic hydrothermal, late) is not well constrained;

5) the massive sulphide mineralization is localized within and immediately on top of permeable, basaltic hyaloclastite units. Dacitic ash (Coad 1976) is a very minor, but perhaps significant component of the hyaloclastite;

6) the massive sulphide lense is copper-rich over the proposed chlorite alteration pipe, and becomes zinc-rich upwards, and away from, this pipe;

These characteristics of the Potter Mine area and deposit are consistent with those of the Noranda-type model. A significant difference between the Potter Mine and deposits in the Noranda camp, is the abundance of komatiitic rocks in the Potter Mine stratigraphy. Notwithstanding the predominance of komatiitic and picritic flows in the Potter Mine area, the presence of certain necessary geological factors have contributed to the concentration of base metal sulphide mineralization in this area. A large heat source, required to initiate a convective hydrothermal system, is manifest as the Centre Hill Complex. A conduit, along which hydrothermal fluids were channelled, is manifest by the possible synvolcanic fault. Zones of permeability, along which hydrothermal fluids can pass and react with wall rock or sea water, are present as hyaloclastite horizons.

The significance of the dacitic ash, reported to be intimately associated spatially with the massive sulphide mineralization (Coad 1976, p. 144) is not so obvious. It may represent the product of fractionation in a high-level magma chamber. Existing chemical analyses of the ash units are not sufficiently comprehensive to test if this unit is chemically similar to the high-silica rhyolites, present in the stratigraphy of many VMS deposits, in the Superior Province (e.g., Lesher et al. 1986). It is reiterated that the ash component within the hyaloclastite is very small (Coad 1976).

Finally, the presence of graphite, of possible organic origin (Coad 1976, p. 62), may provide evidence that biogenic activity was a factor which contributed to the precipitation of the base metal sulphide mineralization.

Gold Depositional Model

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The Porcupine camp is a giant gold camp and a wealth of observational data are available to describe the gold deposits. However, those factors which contributed to the localization of the auriferous fluids in a relatively restricted domain, adjacent to the Destor-Porcupine fault zone, are not entirely clear. Some factors which bear on the depositional model for Archean lode gold mineralization in the Porcupine camp include:

1) when viewed at a greenstone belt scale, gold deposits in the Abitibi greenstone belt, including the Porcupine camp, occur along long, crudely linear corridors traditionally referred to as "breaks" (e.g., Destor-Porcupine fault). These "breaks" consist of ductile to

brittle-ductile shear zones in which an array of narrower brittle to brittle-ductile faults commonly occurs. Sets of brittle-ductile shear zones, historically referred to as "splay-structures" (e.g., Dome fault), commonly occur adjacent to the "breaks", and typically wrap asymptotically into the "break". Traditionally, the "breaks" and "splays" have been considered to be contemporaneous. Gold deposits, with associated alteration (i.e. addition of CO_2, alkalies, and S) typically occur in "splay-structures" but rarely within the "breaks" themselves (e.g. Destor-Porcupine), although the "breaks" may contain anomalous gold and associated alteration of less intensity. In some deposits, late motion along the regional "breaks" post-dated the formation of gold-quartz veins. Does this indicate a different deformation and hydrothermal chronology between the "breaks" and the "splays"? Was gold introduction episodic throughout this history, or was it confined to a specific period during the development of the "breaks" and/or the "splays"?

2) within a camp, gold deposits commonly show a marked asymmetrical distribution relative to the position of the "break". This is true of the Porcupine camp, where virtually all of the gold deposits occur to the north of the Destor-Porcupine fault. However, to the east of the Porcupine camp, the Aquarius, Porcupine Peninsula, and St Andrew Goldfields gold deposits occur along ductile shear zones which lie south of the Destor-Porcupine fault zone. About 100 kilometres east of Timmins, in Harker and Holloway townships, the Holt-McDermott Mine and Canamax Resources East Zone also occur south of the Destor-Porcupine fault zone, along a common ductile shear zone. This regional asymmetrical distribution of gold deposits in this part of the Abitibi greenstone belt has not been adequately addressed;

3) the Hollinger-McIntyre-Coniaurum system and Dome Mine areas were centres of late (2691 to 2688 Ma; Corfu et al. 1989; Marmont and Corfu 1989) plutonism (porphyritic intrusions and breccia pipes; e.g., Burrows and Spooner 1986; Mason and Melnik 1986; Piroshco and Hodgson 1988); approximately 90% of the total gold from the Porcupine camp was extracted from these areas (Table 1). This spatial association between Archean lode gold mineralization and late intrusive bodies has been recognized in other Archean areas (e.g., Rock et al. 1988). In the northeastern part of the Porcupine camp, the source of about 10 percent of the total camp production, felsic intrusions are not abundant (e.g., Hoyle Pond Mine) or are absent (e.g., Pamour #1 and Falconbridge Hoyle Mines);

4) gold mineralization is localized in or adjacent to zones which experienced complex deformation and alteration histories. Whether the deformation was superimposed upon rheologically favourable zones which had been previously altered and mineralized (e.g., Mason et al. 1988) or whether the localization of gold and alteration was part of a complex, progressive deformation event (e.g., Piroshco and Hodgson 1988), remains debated;

5) a crude quartz vein chronology is recognized in many of the gold mines (e.g., Graton et al. 1933; Hall 1985). Steeply dipping quartz veins are related to shear zones (e.g., Stop #1, Hollinger-McIntyre-Coniaurum system, Section 8.2.6.) and commonly are deformed. Shallowly dipping to sub-horizontal quartz veins (i.e. extension veins or "flats"), commonly oriented orthogonal to the regional extension lineation and observed throughout the Porcupine camp, are less deformed relative to the steeply dipping veins. The shallowly dipping auriferous veins are interpreted to have formed later in the deformation history (e.g., Section 8.2.6.).

6) fracture controlled chlorite and sericite alteration (township-scale) and auriferous quartz veins occur in both sheared and unsheared rock (Mason et al. 1988). Hence, ductile shear zones are not always the locus of alteration and quartz veining; however, ductile shear zones always occur in proximity to all gold deposits in the Porcupine camp;

7) two types of alteration are associated with auriferous quartz veins in the Timmins area: Type 1- ferroan dolomite-ankerite + sericite + quartz + albite + pyrite, close to the vein and

chlorite + calcite further away from the veins (Bain 1933; Graton et al. 1933; Hurst 1935; Jones 1948; Fyon and Crocket 1982; Mason and Melnik 1986; Wood et al. 1986; Piroshco and Hodgson 1988); and Type 2- hydromuscovite + carbonaceous material + ferroan dolomite-ankerite + quartz + pyrite, close to the vein and chlorite + calcite further away from the veins (Downes et al. 1984; Section 8.5.6.). Type "1" assemblages occur throughout the Porcupine camp, whereas type "2" assemblages appear to be restricted to the northeastern part of the camp (e.g., Hoyle Pond, Owl Creek, and Bell Creek).

8) ductile shear zones, in which gold mineralization occurs, cut the 2691 to 2688 Ma felsic porphyry intrusions and the 2673 Ma albitite dikes (Wood et al. 1986; Marmont and Corfu 1989). Major, through-going auriferous quartz veins cut the porphyry intrusions (e.g., Hollinger-McIntyre-Coniaurum system; Section 8.2.3.4.), but less prominent quartz veins cut the albitite dikes.

9) the ratios of precious to base metals are markedly different in lode gold versus volcanic-associated, massive, base metal sulphide deposits (e.g., Kerrich and Fryer 1981); however, in the gold mines within the Timmins area, minor amounts of chalcopyrite, sphalerite, and/or galena commonly occur associated with the richer gold shoots (e.g., Dome, Pamour #1 and Falconbridge Hoyle Mines; Sections 8.1.3., 8.3.3.2., and 8.4.3. respectively);

10) the fluid interpreted to have been trapped during the precipitation of gold was of low salinity (< 6 wt % NaCl equivalent), aqueous, but CO_2-bearing, with a moderate to high CO_2 density (0.7 to >1.0 g/cm^3; Smith et al. 1984, Walsh et al. 1988, Wood et al. 1986);

11) homogenization temperatures for the fluid inclusion populations range from 225° to 355° C, (Smith et al. 1984, Walsh et al. 1988, Wood et al. 1984, 1986), with CO_2 phase separation indicated in the Hollinger-McIntyre system (Smith et al. 1984; Wood et al. 1986);

12) calculated and estimated fluid inclusion trapping pressures, determined from isochores for mixed H_2O-CO_2 inclusions, lie in the range of 1.5 to 4.5 kb (Smith et al. 1984) which corresponds to a minimum depth of about four kilometres, assuming lithostatic load. These inclusions may also contain minor amounts (<five volume percent) of CH_4 (Smith et al. 1984, Wood et al. 1986);

13) carbon isotopic values for hydrothermal ferroan dolomite and ankerite in and adjacent to quartz veins in the Porcupine camp range between approximately -5.5 and 0 per mil (PDB); heavier isotopic values occur in areas where carbonaceous metasedimentary units occur (Fyon et al. 1980, 1982, 1983, Spooner et al. 1985, Wood et al. 1986, and Kerrich et al. 1987);

14) sulphur isotopic values for sulphide minerals from the auriferous quartz vein systems in the Owl Creek, Coniaurum, McIntyre-Hollinger, and Dome Mines range between -4 and +7 per mil (CDT; Schwarcz and Rees 1985; Spooner et al. 1985);

15) oxygen isotopic values of vein quartz from several gold deposits in the Timmins area range from +10 to +15 per mil (SMOW; Kerrich and Fryer 1979, Kerrich and Hodder 1982, Fyon et al. 1983, Wood et al. 1986), similar to values recorded for quartz veins from gold deposits elsewhere in the Superior Province and the Yilgarn Block of Western Australia (e.g., Golding and Wilson 1981, 1987)

16) carbonaceous material and iron-rich tholeiitic basalt commonly occur in proximity to gold deposits;

9.3.1. Discussion - Consistency With a Depositional Model

An empirical depositional model, synthesized from observations drawn from many Archean lode deposits, was summarized by Colvine et al. (1988). This depositional model is used as the comparative base, not because it is deemed to be the best, but because it represents a synthesis of observations from across the Superior Province. This particular depositional model is also preferred because a deliberate attempt was made to separate synthesis of the empirical characteristics of the depositional site, from the interpretation of those data.

Across the Superior Province, lode gold mineralization occurs in "splay" structures adjacent to regional structures ("breaks"). The setting and location of the Porcupine camp is consistent in this regard, with gold mineralization occurring in zones adjacent to the Destor-Porcupine fault. The asymmetrical distribution of the Porcupine camp gold mineralization with respect to the Destor-Porcupine fault (along the north side), is also typical of other camps in the Superior Province. However, the factors which culminated to produce this giant camp, in this specific area, are not well understood. Additional structural studies are required about the Destor-Porcupine fault, in the Timmins area, to better document the structural styles, orientations, and chronologies of the Destor-Porcupine fault zone and the subjacent ductile shear zones.

Frequently, reference is made to the spatial and genetic association of felsic intrusions and lamprophyre dikes (e.g., Burrows et al. 1986; Mason and Melnik 1986; Rock et al. 1988) with Archean lode gold mineralization. In the core of the Porcupine camp (Hollinger, McIntyre, Coniaurum and Dome Mine area), a definite spatial association occurs between late, felsic, porphyritic intrusions and gold mineralization (point 3). The paucity of felsic intrusive rocks in the stratigraphic sequences of those mines in the northeastern part of the Porcupine camp (e.g., Pamour #1, Falconbridge Hoyle, Marlhill, Bell Creek, Hoyle Pond Mines) suggests that the presence of late felsic intrusions is an important, but not essential parameter of the depositional environment. However, given the mass of gold that has been extracted from the Hollinger-McIntyre-Coniaurum and Dome systems, where late porphyry intrusions are abundant, it must be acknowledged that the role of the porphyries may not be completely understood. Whether this spatial association reflects a genetic (Mason and Melnik 1986) or passive, structural relationship between the localization of auriferous quartz veins and the porphyry intrusions (Burrows and Spooner 1986) remains debated.

Lamprophyre dikes have also been cited as important components in the gold depositional environment (e.g., Wyman and Kerrich 1989; Rock et al. 1989). In the Porcupine camp, albitite dikes, having chemical characteristics of lamprophyres (Wood et al. 1986), occur in the Hollinger and McIntyre Mines. However, lamprophyre dikes either are not abundant elsewhere in the Porcupine camp, or they have not been sufficiently characterized to infer their lamprophyric affinity. Furthermore, on the scale of the Abitibi greenstone belt, lamprophyres are not unique to gold deposits, and are present elsewhere where gold mineralization is not recorded. Thus, like the late porphyry intrusions, the presence of lamprophyre dikes is a favourable, but not essential characteristic of the depositional environment.

In general, auriferous zones in the Superior Province are characterized by a complex vein and alteration sequence (e.g., Colvine et al. 1988). The gold deposits in the Porcupine camp are consistent with this aspect of the depositional model (point 4). Whether this complexity reflects the integration of a single, complex, progressive deformation - hydrothermal alteration event (e.g., Piroshco and Hodgson 1988) or the selective superimposition of gold mineralization upon pre-existing alteration zones (e.g., Brisbin et al. 1987; Mason et al. 1988) is not resolved. Evidence in favour of a progressive deformation and mineralization event is provided by the crude quartz vein chronology observed in many mines in the Porcupine camp (point 5).

The extent to which regionally extensive fracture arrays were generated in brittle shear zones, and filled with quartz, sericite, carbonate or chlorite (point 6), outside of, but coeval with the ductile shear zones, has not been adequately addressed. That auriferous quartz veins and alteration are not always associated with ductile shear zones is consistent with: a) the early localization of the auriferous veins and related alteration which pre-dated, and was not related to, the development of the ductile shear; b) the localization of the auriferous veins and related alteration within brittle shear zones, synchronous with the development of ductile shear zones; or c) the localization of auriferous quartz veins and related alteration within and during the development of ductile shear zones, but within low-strain lithons which served as favourable, brittle hosts. In the case of possibility "a", the ductile shear fabric may have been localized in highly altered rocks because of their suitable alteration mineralogy which formed prior to the development of the ductile shear zones (e.g., Brisbin et al. 1987; Mason et al. 1988). Additional detailed structural and alteration studies are required to test these hypotheses.

In the depositional model, the geometry of auriferous quartz vein arrays is strongly dependent on the response of the host rock to the ambient stress regime. In parts of the Porcupine camp, quartz veins commonly developed along zones of anisotropy and structural weakness, such as flow contacts (e.g., Hollinger-McIntyre-Coniaurum system and Bell Creek Mine, Sections 8.2.3. and 8.6., respectively). Quartz veins in the Falconbridge Hoyle Mine are preferentially developed in the competent Pamour conglomerate, relative to the more incompetent slatey metasedimentary rocks (Section 8.4.). Preliminary analysis of quartz vein orientations in the Hollinger-McIntyre-Coniaurum system (Section 8.2.6.) are consistent with a coherent stress regime, for which the principal compressive stress was oriented in a north-northwesterly direction (Rye and Edmunds, Section 8.2.6.). This resolved principal stress orientation is similar to that proposed by Stott et al. (1987) to account for the late tectonic history in the northwestern part of the Superior Province in Ontario, and suggests that gold mineralization across the southern part of the Superior Province may have formed in a consistent stress regime (e.g., Colvine 1989, Fyon et al. 1989). Many more detailed observations are required, across a wider geographic area, to test this hypothesis.

The sericite-ferroan dolomite-ankerite alteration developed about quartz veins (point 7) in the Porcupine camp (e.g., Bain 1933; Piroshco and Hodgson 1988) is consistent with the empirical depositional model synthesized by Colvine et al. (1988). However, the "grey zone" alteration, characterized by the presence of carbonaceous material and hydromuscovite (Section 8.5.4.) in the Bell Creek, Marlhill, Owl Creek, and Hoyle Pond deposits, was not described in the depositional model. This alteration type is not commonly reported elsewhere from the Superior Province. Is this because the carbon-bearing assemblage is not as easily recognized, or is the assemblage truly uncommon across the Superior Province? Additional alteration studies are required, particularly where carbonaceous metasedimentary units are present within a mine stratigraphy.

The absolute age of gold mineralization is difficult to constrain. Attempts have focused on constraining the maximum age of gold mineralization. Available geochronological data, summarized by Colvine et al. (1988) and Marmont and Corfu (1989) are consistent with the introduction of gold during the later Archean tectonic history of the Superior Province. In the Porcupine camp, prominent, through-going, auriferous quartz veins cross-cut and therefore, post-date the emplacement of 2691 to 2688 Ma (Corfu et al. 1989; Marmont and Corfu 1989) porphyry intrusions (point 8). Less prominent auriferous quartz veins also cut a 2673 Ma (Corfu et al. 1989; Marmont and Corfu 1989) deformed and altered albitite dike in the Hollinger Mine (Wood et al. 1986). These relationships are consistent with: a) the protracted introduction of gold during a period which began after the emplacement of the porphyry intrusions, and continued after the emplacement of the albitite dike; b) the introduction of all gold following the emplacement of the albitite dike; c) the introduction of all gold following the emplacement of the porphyry intrusions, but prior to the emplacement of the albitite dike. In the case of possibility "c", auriferous quartz veins which cross-cut the albitite would represent the products of local remobilization of gold into the dike during its emplacement. Hydrothermal sericite adjacent to auriferous quartz veins in the Dome, Hollinger, and Davidson Tisdale Mines have $^{40}Ar/^{39}Ar$ dates of 2633+/-6 Ma, 2617+/-8 Ma (Masliwec et al. 1986) and 2615+/-2 Ma (Hanes et al. 1987), respectively. These mica dates may mark: a) the age of the gold-related, hydrothermal alteration; b) the time at which the hydrothermal micas cooled through their thermal blocking temperatures, some time after the introduction of gold and attendant alteration; or c) the thermal influence of an event that was not directly related to gold mineralization. Wong et al. (1989) have also recorded young hydrothermal mica ages (2579+/-3 Ma) in the Sigma Mine (Val d'Or), indicating that young mica ages are not unique to the Timmins area, but occur elsewhere in the southern Abitibi greenstone belt. Thus, available geochronological evidence indicates that quartz vein formation and sericitization of wall rock adjacent to quartz veins were younger than the porphyry emplacement in the Timmins area, but how much younger is not certain.

Detailed mineralogical and paragenetic descriptions are relatively rare for Archean lode gold deposits in the Superior Province (e.g., Ebbutt 1948); hence, the depositional model synthesized by Colvine et al. (1988) did not consider accessory sulphide mineralogy in the gold deposits. Minor amounts of base-metal sulphide minerals generally occur in most Archean lode gold systems (e.g., Hutchinson 1987), and the deposits in the Porcupine camp are consistent in this regard (point 9).

Within Archean lode gold deposits in the Superior Province, including the Hollinger-McIntyre and Pamour #1 Mines, fluids from which quartz veins precipitated show a marked similarity in their light stable isotopic and compositional characteristics (see data compilations in Colvine et al. 1988). Regardless of its origin, it appears that the hydrothermal fluid from which the quartz veins precipitated in the Porcupine camp, was similar to that from which other Archean lode gold deposits formed.

Colvine et al. (1988) postulated that Archean lode gold deposits represent a depositional spectrum, and that the upper parts of this spectrum are characterized by the development of quartz veins, whereas sulphide impregnation zones were interpreted to have formed at a deeper crustal level. The preserved parts of the Archean lode gold systems are interpreted to have formed at deeper crustal levels (ca. two to ten kilometres) compared to Tertiary epithermal deposits (e.g., Colvine et al. 1988). The inferred depth at which mineralization in the Porcupine camp formed, approximately 1.5 to 4.5 kilometres depth (Smith et al. 1984; point 12), is consistent with estimates for other Archean lode gold deposits in the Superior Province.

Although mechanisms of gold precipitation have not been addressed in this field guide, it is perhaps significant that many of the deposits occur within sequences which contain carbonaceous metasedimentary and iron-rich metavolcanic rocks (point 16). In these areas (e.g., Hollinger and Pamour #1 Mines), hydrothermal carbonates have heavier carbon isotopic values (0 per mil, PDB; e.g., Fyon et al. 1983) and CH_4 becomes a persistent species in the fluid inclusions (Smith et al. 1984, Wood et al. 1986, Spooner et al. 1987). These characteristics suggest that the carbonaceous material may have reacted with the hydrothermal fluid to enhance the precipitation of gold (e.g., Downes and Fyon 1985; Fyon 1986a,b). Iron-rich tholeiitic basalt, present in the depositional environment (point 16), may provide a similar function by disrupting the hydrothermal fluid chemistry (e.g., Latulippe 1976).

Most of the features observed in the gold mines examined during this tour are consistent with the empirical depositional model formulated by Colvine et al. (1988). Alteration, quartz vein mineralogy and paragenetic relationships, and vein and alteration chronology remain aspects of the depositional model which require further refinement and expansion.

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