GEOLOGY, GEOCHEMISTRY AND METALLOGENIC ZONING IN THE HEDLEY GOLD-SKARN CAMP (92H/08; 82E/05)

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INTRODUCTION

This paper is an update to the preliminary results presented by Ray *et al.* (1987) for the Hedley mapping project conducted by the British Columbia Geological Survey Branch. The Hedley district encompasses an area of 525 square kilometres and is situated in southern British Columbia, approximately 40 kilometres east-southeast of Princeton (Figure 1-5-1).

The Hedley area has a long history of gold mining (Camsell, 1910; Billingsley and Hume, 1941; Dolmage and Brown, 1945) and between 1902 and 1955 approximately 51 million grams of gold were won from several gold-copper skarn orebodies (Table 2-10-1, Ray *et al.*, 1987). More than 95 per cent of the gold production in the camp came from one deposit which was worked at the Nickel Plate and Hedley Mascot mines; only smaller amounts were obtained from the French, Goodhope and Canty auriferous skarn deposits. Exploration interest in the Hedley gold camp has been revitalized by the recent reopening of the Nickel Plate mine by Mascot Gold Mines Limited as a 2450-tonne-per-day open-pit operation.

The gold-skarn mineralization is hosted in Upper Triassic Nicola Group rocks and is genetically related to a suite of dioritic intrusions of probable early Jurassic age. A series of facies changes recognized within the Nicola succession is related to deposition across a fracture-controlled basin margin; it is economically important as the gold-skarn mineralization is lithologically, stratigraphically and structurally controlled.

A district-wide metallogenic zoning may exist in the Hedley camp with gold and arsenic-rich skarns developed in the west and tungsten-rich and gold and arsenic-poor skarns in the east. This type of zoning may have exploration significance elsewhere in the North American Cordillera.

DISTRICT GEOLOGY

The Hedley camp lies within the Intermontane Belt of the Canadian Cordillera and the overall geology of the district is presented in Figure 1-5-1. The geology has been described by Bostock (1930, 1940a, 1940b) and more recently by Ray *et al.* (1986, 1987; Ray and Dawson, (1987, 1988).

The southeastern margin of the area is underlain by highly deformed ophiolitic cherts, argillites, tuffaceous siltstones, greenstones and minor limestones of the Apex Mountain complex, containing Upper Devonian, Carboniferous and Middle to Late Triassic microfossils (Milford, 1984; J.W.H. Monger, personal communication, 1985). The complex and the supracrustal rocks further west are separated by either intrusive rocks or major faults, and it is uncertain whether their original contact represents an unconformity or a suture zone.

The area between Winters and Whistle creeks is largely underlain by sedimentary and volcaniclastic rocks of the Upper Triassic Nicola Group and the Lower Cretaceous Spences Bridge Group; the generalized stratigraphy of these sequences in the district is shown in Figure 1-5-2.

Three distinct stratigraphic packages are recognized within the Nicola Group. The oldest, informally called the Peachland Creek formation*, comprises massive, mafic, quartz-bearing andesitic to basaltic ash tuff and minor chert-pebble conglomerate. Locally the formation contains large disrupted limestone units which are interpreted to be olistoliths. This previously unrecognized basal unit of the Nicola Group is poorly exposed in the Hedley district but is identified in several localities, notably as a small fault slice adjacent to the Bradshaw fault northeast and southwest of Hedley township, just north of Winters Creek, in the vicinity of the French and Goodhope mines, and south-southeast of the Nickel Plate mine where it is exposed adjacent to the Cahill Creek fracture zone (Figure 1-5-1).

The Peachland Creek formation is stratigraphically overlain by a sedimentary sequence 100 to 700 metres thick in which a series of east-to-west facies changes are recognized. This sequence progressively thickens westward (Figure 1-5-2) and the facies changes probably reflect deposition across the tectonically controlled margin of a northwesterly deepening late Triassic marine basin.

The easternmost and most proximal facies, informally called the French Mine formation (Figures 1-5-2 and 1-5-3), has a maximum thickness of 150 metres and comprises massive to bedded limestone interlayered with thinner units of calcareous siltstone, chert-pebble conglomerate, tuff, limestone-boulder conglomerate and limestone breccia. The

* This is named after a major tuffaceous sequence which underlies the Hedley Formation in the Pennask Mountain area, approximately 30 kilometres west of Peachland (Dawson and Ray, 1988).

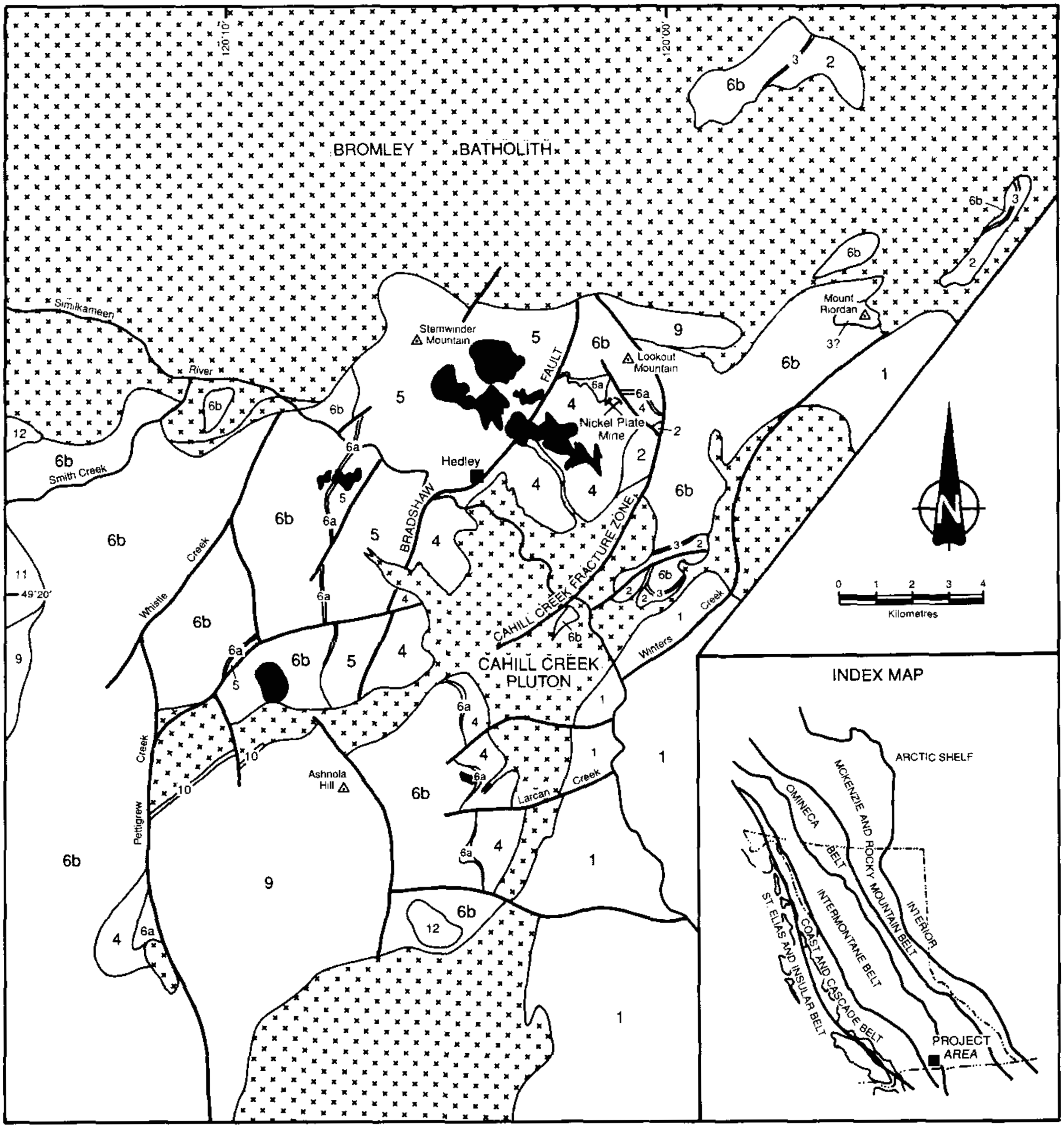

Figure 1-5-1. Regional geology of the Hedley district, southern British Columbia. Legend on facing page.

formation hosts the auriferous skarn mineralization at the French and Goodhope mines (Figure 1-5-2).

Further west, rocks stratigraphically equivalent to the French mine formation are represented by the informally named Hedley formation which hosts the gold-bearing skarn at the Nickel Plate mine. The Hedley formation is 400 to 500 metres thick and characterized by thinly bedded, turbiditic calcareous siltstone and units of pure to gritty, massive to bedded limestone that reach 75 metres in thickness and several kilometres in strike length. The formation also includes lesser amounts of argillite, conglomerate and bedded tuff; locally the lowermost portion includes minor chert-pebble conglomerate.

The westernmost, more distal facies is represented by the Stemwinder Mountain formation (Figures 1-5-2 and 1-5-3) which is at least 700 metres thick and characterized by a monotonous sequence of black, organic-rich, thinly bedded calcareous argillite and turbiditic siltstone, minor amounts of

LEGEND

TERTIARY

12 Basaltic flows

EROSIONAL UNCONFORMITY

EARLY CRETACEOUS

11 VERDE CREEK INTRUSION – *granite and microgranite*

10 RHYOLITE INTRUSION – *quartz porphyry*

9 SPENCES BRIDGE GROUP – *andesitic to dacitic pyroclastics and flows with minor sediments*

CONTACT UNCERTAIN

EARLY JURASSIC

8 BROMLEY BATHOLITH AND CAHILL CREEK PLUTON – *granodiorite to quartz monzodiorite*

7 HEDLEY INTRUSION – *quartz diorite, diorite, and gabbro*

INTRUSIVE CONTACT

NICOLA GROUP

LATE TRIASSIC

6b WHISTLE CREEK FORMATION – *bedded to massive ash and lapilli tuff, minor tuffaceous siltstone*

6a Copperfield Conglomerate – *limestone boulder conglomerate*

5 STEMWINDER MOUNTAIN FORMATION (WESTERN FACIES) – *thinly bedded argillite and limestone*

4 HEDLEY FORMATION (CENTRAL FACIES) – *thinly bedded siltstone, thick limestone beds and minor tuffs*

3 FRENCH MINE FORMATION (EASTERN FACIES) – *limestone, limestone breccia and pebble conglomerate*

2 PEACHLAND CREEK FORMATION – *basaltic ash tuffs and flows with minor limestone and chert-pebble conglomerate*

CONTACT OCCUPIED BY CAHILL CREEK PLUTON

PALEOZOIC

1 APEX MOUNTAIN COMPLEX – *ophiolite sequence of cherts, greenstones, siltstones, argillites and minor limestones*

siliceous fine-grained tuff and dark impure limestone beds that seldom exceed 3 metres in thickness.

Conodonts of Late Carnian to Middle Norian age were obtained from limestones in the Hedley and Stemwinder Mountain formations (M.J. Orchard, personal communications, 1985, 1986; Ray and Dawson, 1987). Paleocurrent measurements suggest that the rocks in both formations were derived from an easterly source. The French Mine formation was laid down in a proximal, shallow, possibly forereef marine environment that received deposition of angular limestone breccias and chert-pebble conglomerates. Deposition of the more distal Hedley formation involved slower, more turbiditic sedimentation with the occasional influx of coarser conglomerate, tuff and coarse gritty limestone. The limestones and calcareous siltstones are characterized by a general absence of both bioturbation and shelly fossils, although some crinoid ossicles, rare solitary corals, bivalve fragments and belemnites are present.

Deposition of the Stemwinder Mountain formation was characterized by fine-grained, slow sedimentation, a high organic content and only very minor limestone development. Although laid down in deeper water, the formation is not oceanic, but was probably deposited within the deeper part of a relatively shallow back-arc basin that formed east of the main Nicola volcanic arc.

The sedimentary rocks of the Stemwinder Mountain, Hedley and French Mine formations pass stratigraphically upward into the Whistle Creek formation (Figures 1-5-2, 1-5-3) which is probably late Triassic in age. The formation is 700 to 1200 metres thick and distinguishable from the underlying rocks by a general lack of limestones and a predominance of andesitic volcaniclastic material. Its lower portion contains tuffaceous, often turbiditic siltstone and rare argillite, but the uppper part of the succession is characterized by bedded to massive crystal ash and lapilli tuff with minor volcanic breccia. The tuffs commonly contain augite and plagioclase crystals that show no evidence of mechanical transport or physical abrasion. The base of the Whistle Creek formation is often marked by the Copperfield conglomerate (Figures 1-5-2, 1-5-3), a limestone-boulder conglomerate that forms the most distinctive and important stratigraphic marker horizon in the district. The conglomerate is well developed west of Hedley where it forms a northerly trending, steeply dipping unit that is traceable for over 15 kilometres along strike. The same conglomerate outcrops in small areas within upfaulted slices along Pettigrew Creek to the south, and as outliers near Nickel Plate and Lookout mountains to the east (Figure 1-5-1).

The Copperfield conglomerate is described in detail by Ray *et al.* (1987). It locally reaches 200 metres in thickness but is often less than 10 metres wide. It varies from clast to matrix-supported and is characterized by abundant, well-rounded to angular pebbles, cobbles and boulders of limestone, generally up to 1 metre in diameter. Rare limestone blocks up to 15 metres in diameter are locally present, usually at the base of the unit. Some limestone boulders contain crinoid ossicles and, in one instance, fragments of a Triassic shallow-water marine bivalve possibly belonging to the family *Carditidae* (H. Tipper, personal communication, 1987; Geological Survey of Canada Location No. C-143201). Conodonts extracted from some limestone clasts give Carnian ages (M.J. Orchard, personal communication, 1985, 1986), while radiolaria of Permian age were collected from one chert pebble (F. Cordey, personnel communication, 1985). To determine the locations of these fossiliferous samples *see* Ray and Dawson, 1987.

The Copperfield conglomerate is interpreted to be an olistostrome (Ray *et al.*, 1987), presumably derived from an upslope source to the east. Locally, the larger limestone blocks were autobrecciated during their catastrophic downslope movement and some large siltstone clasts exhibit soft-sediment deformation structures, suggesting they were unconsolidated when incorporated into the conglomerate.

Although the main tuffaceous sequence of the Whistle Creek formation is widely developed and overlies the Stemwinder Mountain, Hedley and French Mine formations, the Copperfield conglomerate has only been identified overlying the Stemwinder Mountain and Hedley formations (Figure

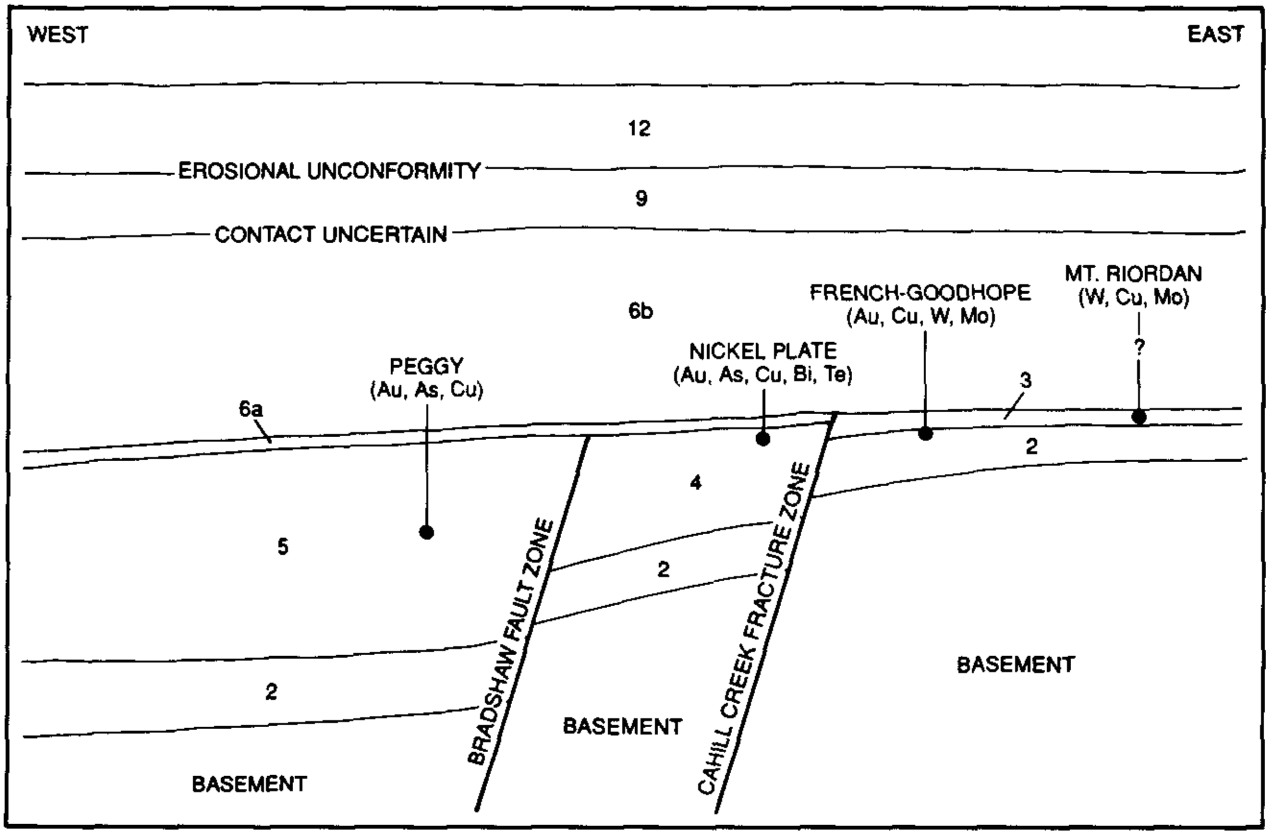

Figure 1-5-2. Schematic east-west stratigraphic section of the Hedley district showing location of skarn mineralization in relation to sedimentary facies changes (*see* Figure 1-5-1 for legend).

1-5-3). However, angular limestone breccias and conglomerates within the French Mine formation were possibly the source material for the Copperfield conglomerate. No east-to-west facies changes are recognized in the main tuffaceous sequence of the Whistle Creek formation.

The Whistle Creek formation is overlain by volcaniclastic rocks that may belong to the Early Cretaceous Spences Bridge Group (Figure 1-5-2). Two different sequences are recognized whose relationship to one another is unknown. One of these lies between Smith and Whistle creeks on the western edge of the map sheet (Figure 1-5-1) and comprises dark-coloured, massive dacitic flows with lesser amounts of dacitic ash, and dust tuff and pale to maroon-coloured ignimbritic rocks. Many ignimbrites display fiammé textures and welded features; in some localities they are associated with thin units of heterogeneous, coarsely clastic rocks that are interpreted to be lahars. The other suite of Spences Bridge Group contains two distinct stratigraphic units but no volcanic flows. It occurs as outliers at two separate localities; the smallest covers less than 4 square kilometres and lies east of Lookout Mountain, while the other covers 40 square kilometres surrounding Ashnola Hill* (Figure 1-5-1). The lowest stratigraphic unit in this suite, which is present in both outliers, has a maximum thickness of 300 metres and largely comprises massive grey-coloured ash and crystal tuffs of probable dacite composition. These tuffs contain rounded, highly embayed quartz crystals and sporadic angular lapilli of dacite, rhyolite and quartz porphyry. Some fiammé-textured welded tuffs, minor tuffaceous siltstones and bedded crystal tuffs are also present locally.

In the southern outlier, west of Ashnola Hill, the lowermost quartz-bearing dacitic tuff unit is stratigraphically overlain by a sequence of fresh, massive, dark green crystal lithic tuffs 200 metres thick. This uppermost unit in the Spences Bridge Group is characterized by abundant large euhedral plagioclase crystals, and is of andesitic to basaltic composition.

The Ashnola Hill outlier occupies a broad syncline, plunging gently to the north, that is cut by faults along the northern, western and eastern margins. It is uncertain whether the contact between Spences Bridge Group and the underlying rocks represents an unconformity or a thrust plane. In the Princeton area, west of the Hedley district, Preto (1979) mapped subaerial flows, ash flows and lahars in the Spences Bridge Group and noted a basal unconformity; these rocks resemble the Spences Bridge suite between Smith and Whistle creeks. No unconformity is identified in the Hedley district and no evidence of paleoweathering is observed in the underlying rocks. The Lookout Mountain outlier forms a thin, flat-lying unit that locally overlies plutonic rocks, yet it shows no signs of thermal hornfelsing. Both outliers may represent thrust slices.

* Ashnola Hill is an unofficial name given to the hill surmounted by the British Columbia Telephone Company microwave tower.

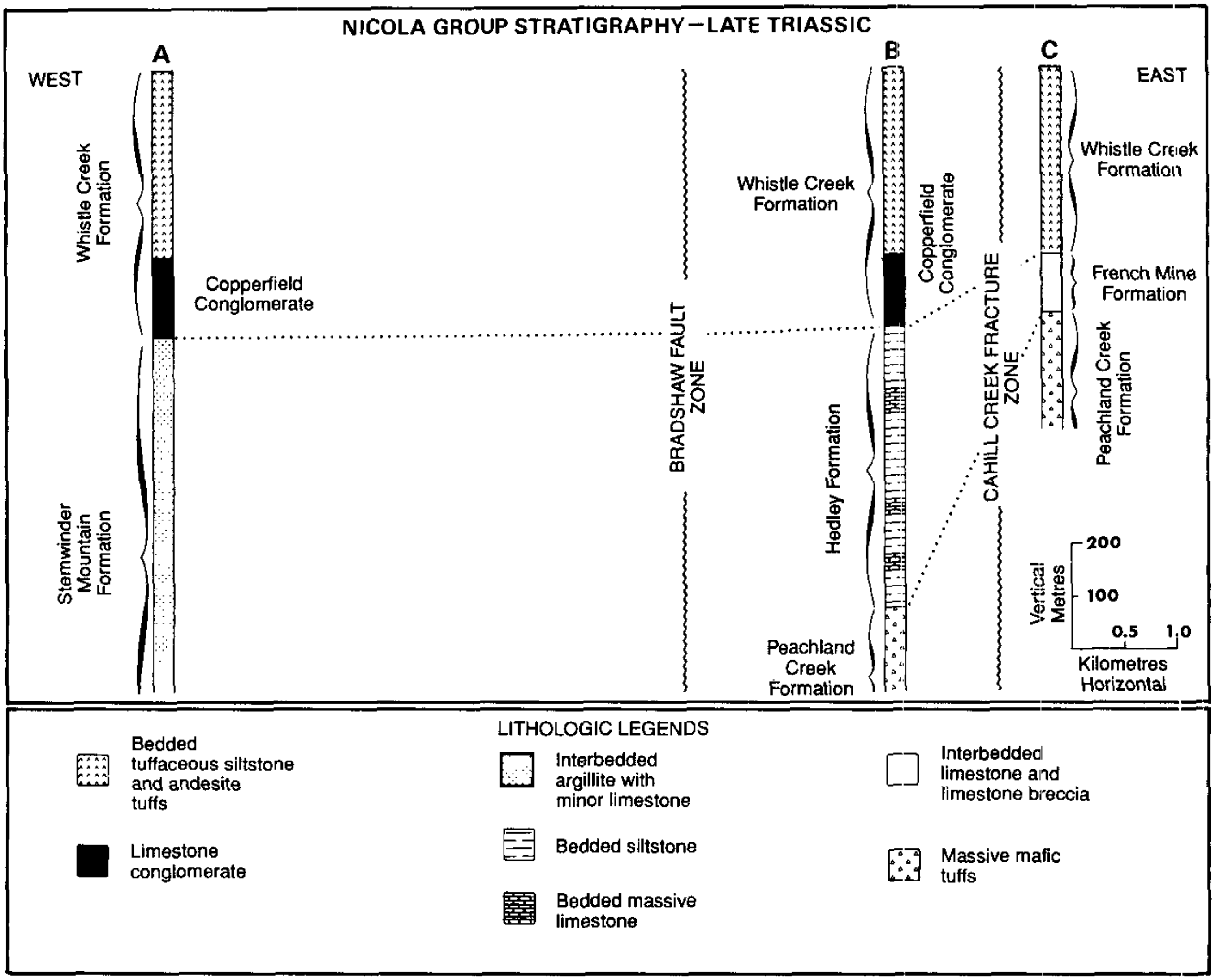

Figure 1-5-3. Comparative east-west stratigraphic sections in the Nicola Group, Hedley district: A = Stemwinder Mountain area west of Peggy mine; B = Nickel Plate mine area; C = French mine area.

Three plutonic suites are recognized in the area. The oldest, the Hedley intrusions, is economically important and probably Early Jurassic in age. It forms major stocks up to 1.5 kilometres in diameter and swarms of thin sills and dykes up to 200 metres in thickness and over 1 kilometre in length. The sills and dykes are coarse grained and massive diorites and quartz diorites with minor gabbro, while the stocks range from gabbro through granodiorite to quartz monzonite. Many of the sills and dykes are porphyritic and characterized by coarse phenocrysts of hornblende and zoned plagioclase. When unaltered they are dark coloured, commonly contain minor disseminations of pyrite and pyrrhotite and are often rusty weathering. By contrast, the skarn-altered diorite intrusions are usually pale coloured and bleached.

The Hedley intrusive suite is absent in the Apex Mountain complex, but invades the Upper Triassic rocks over a broad area. Varying degrees of sulphide-bearing calcic skarn alteration are developed within and adjacent to many of these intrusions, particularly the dyke and sill swarms. Some previous workers (Billingsley and Hume, 1941; Dolmage and Brown, 1945) considered this plutonic suite to be genetically related to the skarn-hosted gold mineralization in the district, including that at the Nickel Plate, Hedley Mascot, French and Goodhope mines; the geochemical and mapping results presented in this paper support this conclusion.

The second plutonic suite comprises coarse-grained, massive biotite hornblende granodiorite to quartz monzodiorite of presumed Early Jurassic age. It generally forms large bodies, for example, the Bromley batholith (Monger, personal communication, 1987) which outcrops northwest of Hedley, and the Cahill Creek pluton which generally separates the Nicola Group rocks from the highly deformed Apex Mountain complex further southeast. North of Ashnola Hill a dyke-like apophysis of the Cahill Creek pluton is controlled by a west-southwest extension of the Cahill Creek fracture zone. Other narrow, elongate apophyses intrude the Nicola Group southwest and east of Hedley and are also controlled by northwesterly to westerly trending lineaments. Country rocks up to 1.5 kilometres from the margins of the Bromley batholith and Cahill Creek pluton are hornfelsed; some minor skarn alteration is also locally present adjacent to the pluton, but it is generally sulphide poor and not auriferous.

Most potassium-argon dates from the Cahill Creek pluton range from 150 to 160 Ma (Roddick *et al.*, 1972). However, a $^{207}Pb/^{206}Pb$ dates for two discordant zircon fractions give dates of 196 and 199 Ma respectively (P. van der Heyden, personal communication, 1987).

The third and youngest intrusive suite includes two rock types that are possibly coeval and related to the formation of the dacitic volcaniclastic rocks within the Spences Bridge Group. One of these, the Verde Creek stock (J.W.H. Monger, personal communication, 1987), outcrops at the western edge of the map sheet, south of Smith Creek. It comprises a fine to medium-grained, massive leucocratic microgranite that contains minor biotite. The other type is represented by fine-grained, leucocratic, felsic quartz porphyry that contains rounded, deeply embayed quartz phenocrysts up to 4 millimetres in diameter. Sills and dykes, generally less than 3 metres wide, are widespread but not abundant in the area. However, west of Ashnola Hill a dyke-like body of quartz porphyry, 100 to 200 metres wide, follows the margin of the Cahill Creek pluton for a distance of 3.3 kilometres (Ray and Dawson, 1987). The phenocrysts in these rocks are identical to the embayed quartz crystals in the lower dacite tuff unit of the Spences Bridge Group, and it is possible that the dykes and sills were feeders for the Spences Bridge volcaniclastic rocks.

Some of the quartz porphyry intrusions and the Spences Bridge Group around Ashnola Hill are overprinted by narrow zones of silicification containing minor pyrite, abundant epidote (as veinlets and large clots) and trace amounts of small euhedral blood-red garnet crystals.

GEOLOGICAL AND STRUCTURAL HISTORY

The postulated sequential geological history of the area is as follows:

(1) Deposition of the presumed Triassic mafic extrusive rocks of the Peachland Creek formation. The depositional environment is unknown, however, the presence of rare limestone olistoliths suggests tectonic instability.

(2) Late Triassic deposition of the Stemwinder Mountain, Hedley and French Mine formations by westerly to northwesterly directed paleocurrents across a tectonically controlled basin margin. This shallow marine basin deepened to the northwest; the Stemwinder Mountain rocks were laid down on the more distal, deeper basin floor, while the Hedley and French Mine formations were deposited in a shallower environment closer to the shoreline.

(3) Sudden collapse of the basin margin, possibly due to the initiation of the Nicola arc further west, led to the widespread deposition of the Whistle Creek formation, including the initial, gravity-slide deposits represented by the Copperfield conglomerate.

(4) Following lithification of the Nicola Group rocks, two distinct phases of folding took place but the relative age of these phases is uncertain. One phase resulted in a major, north-northeasterly striking, easterly overturned asymmetric anticline which is the dominant structure in the district. The axial plane of the fold dips steeply west, the axis runs subparallel to Cahill Creek, and the core of the anticline is occupied by both the Cahill Creek pluton and rocks of the Peachland Creek formation. A related, but poorly developed, northerly striking axial planar cleavage is present in some argillites and the axes of smaller scale folds related to this deformation dip gently north and south.

The asymmetric anticlinal folding was accompanied by the development of several high-angle, easterly directed, northerly striking reverse faults. The largest of these faults makes up the Cahill Creek fracture zone (Figure 1-5-1) which runs subparallel to both Cahill Creek and the axial plane of the major antiform. Along the Cahill Creek fracture zone, rocks of the Peachland Creek formation were upthrown eastwards against overturned, easterly younging Whistle Creek formation; this suggests an overall vertical movement of at least 400 to 500 metres (the estimated thickness of the Hedley formation at this location). Further west, a similar westerly dipping fracture, the northerly trending Bradshaw fault, is related to a major monoclinal flexure in the sedimentary rocks. Along the Bradshaw fault, steeply dipping rocks of the Stemwinder Mountain formation are upthrown against the gently dipping Hedley formation to the east.

The other phase of folding recognized in the district is economically important as it took place during the emplacement of the Hedley intrusions and partly controlled the late-magmatic auriferous skarn mineralization. It produced the small-scale northwesterly striking, gently plunging fold structures that are an ore control at the Nickel Plate mine (Billingsley and Hume, 1941; Dolmage and Brown, 1945) as well as a series of westerly to northwesterly trending fractures. Although there was little movement along these fractures, they did control the emplacement of the Hedley intrusive dykes and the elongate Banbury, Stemwinder and Toronto stocks.

(5) Emplacement of the Hedley intrusions was shortly followed by intrusion of the Cahill Creek pluton; this probably occurred more than 200 million years ago and it is possible that the two magmatic episodes were genetically related. Both the Hedley intrusions and the Cahill Creek pluton were intruded after the main movement occurred along the Bradshaw fault.

(6) Deposition of the Early Cretaceous Spences Bridge Group and the intrusion of some related quartz porphyries followed a period of uplift and erosion.

(7) Some outliers of the Spences Bridge Group may represent thrust slices, suggesting that the Hedley area underwent a post-Early Cretaceous phase of regional thrust faulting. The Spences Bridge Group has been gently warped and folded by open, northeast-striking folds with subhorizontal axes.

(8) The younger tectonism in the district involved reactivation of the Bradshaw fault and Cahill Creek fracture

zone, as well as some faulting along Whistle and Pettigrew creeks (Figure 1-5-1). The Spences Bridge Group was cut by a series of northerly trending normal faults; some of the very old northwesterly to westerly striking fractures which controlled the Hedley intrusive dykes at the Nickel Plate mine were also reactivated during this episode.

GEOLOGICAL UPDATE ON THE NICKEL PLATE MINE

The following data are based both on older studies (Camsell, 1910; Warren and Cummings, 1936; Billingsley and Hume, 1941; Dolmage and Brown, 1945; Lee, 1951) and on more recent work by the geological staff of Mascot Gold Mines Limited.

The Nickel Plate and Hedley Mascot mines were largely developed on a single, very large, westerly dipping skarn-related gold deposit. It was discovered in 1898 and mined in several underground operations until 1955; it produced approximately 48 million grams of gold from 3.6 million tonnes of ore. Open-pit production resumed in April 1987 at a rate of 2450 tonnes of ore per day; on November 18, 1987 Mascot Gold Mines Limited reported calculated mineable reserves of 8.9 million tonnes grading 4.56 grams gold per tonne.

The gold deposit is hosted within the upper part of the Hedley formation where a zone of garnet-pyroxene skarn alteration, up to 300 metres thick and over 6 square kilometres in area, is developed peripherally to the Toronto stock and swarms of Hedley intrusion dykes and sills. The alteration zone is subcircular in outcrop shape and westerly dipping, subparallel to, but locally crosscutting the gently dipping host rocks which comprise calcareous and thin-bedded siltstone with some impure limestone. Swarms of Hedley diorite porphyry sills 1 to 15 metres in thickness, locally make up to 40 per cent of the skarned interval. In addition, several diorite porphyry dykes have followed west to northwesterly trending fault zones and the mineralization and alteration tends to follow these dykes, forming deep keels of skarn that extend below the main alteration envelope. Skarn development is mostly confined to the Hedley formation, but alteration does extend upwards into the overlying Copperfield conglomerate.

The main episode of skarn development occurred during a period of northerly striking fold deformation shortly after the emplacement of the diorite sills. Most of the sills and dykes within the skarn envelope are bleached and altered. The exoskarn is dark green to brown coloured and typically consists of alternating layers of garnet-rich and clinopyroxene-rich material which reflect the original sedimentary bedding. The concentric mineralogical zoning observed in other small skarn envelopes in the district (Ray *et al.*, 1987) is not clearly defined at the Nickel Plate mine, probably due to large-scale multiple and complex overprinting of the skarn alteration. Garnet-rich skarn is usually found in the cores of the alteration envelopes but metasomatic overprinting has eliminated most of the initial biotite hornfelsing, resulting in a generally sharp transition from pyroxene skarn to unaltered sediment. This transition represents the economically important "marble line" described by Billingsley and Hume (1941). Preliminary studies suggest that at least two stages of mineral growth are present in the skarn. The main minerals formed during the early stage were iron-rich pyroxene, garnet, quartz, wollastanite, scapolite and carbonate. The pink to brown-coloured garnet is generally poorly crystalline except where it grew adjacent to carbonate. The later stage of skarn alteration is largely restricted to the outer and lower margins of the envelope, normally within 100 metres of the skarn front. This late-stage alteration is rarely seen in the central or upper part of the skarn zone, except along fractures or dyke and sill margins. It resulted in the introduction of sulphides and gold, accompanied by the growth of calcite and quartz with minor amounts of epidote, chlorite, clinozoisite and local late-stage axinite. However, the ferro magnesian minerals at the Nickel Plate mine, and in other skarns throughout the district, are remarkably unaltered and display little evidence of widespread propyllitic alteration.

The gold-bearing sulphide zones normally form semiconformable, tabular bodies situated less than 100 metres from the outer and lower skarn margin. They are both lithologically and structurally controlled along northwesterly plunging minor folds, fractures and sill-dyke intersections (Billingsley and Hume, 1941; Dolmage and Brown, 1945)

There is significant geochemical and mineralogical variation throughout the deposit. The main Nickel Plate ore zone, in the northern part of the deposit, consists primarily of arsenopyrite, pyrrhotite and chalcopyrite with calcite, diopside and quartz. Arsenopyrite often forms coarse, wedge-shaped crystals up to 1 centimetre in length and the sulphides occur as disseminations and fracture fillings within the exoskarn. The Sunnyside ore zones in the central part of the deposit are strongly controlled by either sill-dyke intersections or fold hinges. Although the sulphide mineralogy and textures resemble those in the Nickel Plate zone, pyrrhotite dominates in the Sunnyside zones. The Bulldog zone, in the southern part of the deposit, comprises lenses and pods of massive to semimassive sulphide mineralization; it is noticeably richer in chalcopyrite and contains higher silver and zinc values.

Grain boundary relationships suggest the following three stages of sulphide deposition: (1) pyrite; (2) arsenopyrite and gersdorffite (NiAsS); and (3) pyrrhotite, chalcopyrite and sphalerite. Gold mineralization is related to the latter two stages, and minor amounts of magnetite are associated with the first and last sulphide phases. Pyrrhotite and arsenopyrite are the most common sulphides. Present in lesser amounts, but locally dominant, are pyrite, chalcopyrite, gersdorffite and cadmium-rich sphalerite with minor amounts of magnetite and cobalt minerals. Trace minerals include galena, native bismuth, gold, electrum, tetrahedrite, native copper, marcasite, molybdenite, titanite, bismuth tellurides (hedleyite, tetradynite), cobaltite, erythrite, pyrargyrite and breithauptite. Trace amounts of maldonite (Au_2Bi) have recently been identified (A.D. Ettlinger, personal communication, 1987) but no scheelite has been seen in the deposit. The native gold, with hedleyite, occurs as minute blebs, generally less than 25 microns in size, within and adjacent to grains of arsenopyrite and gersdorffite. In the Bulldog zone, electrum occurs in close association with chalcopyrite, pyrrhotite, sphalerite and native bismuth; it tends to be concentrated in microfractures within and around the sulphides.

A recent preliminary statistical study, based on analyses of over 300 samples from various ore zones in the Nickel Plate deposit, showed the following correlation coefficients:

Au:Bi	=	0.94
Ag:Cu	=	0.84
Bi:Co	=	0.62
Au:Co	=	0.58
Au:As	=	0.46
Au:Ag	=	0.28
Au:Cu	=	0.17

The strong positive correlation between gold and bismuth reflects the close association of native gold with hedleyite, while the moderate positive correlation between gold, cobalt and arsenic confirms the observed association of gold, arsenopyrite and gersdorffite. The high positive correlation between silver and copper may indicate that some silver occurs as a lattice constituent in the chalcopyrite. The gold and silver values are relatively independent of each other despite the presence of electrum, and there is generally a low correlation between gold and copper. Gold to silver ratios in the Nickel Plate and Sunnyside zones are greater than 1 with silver averaging 2 ppm. By contrast, in the Bulldog zone where electrum is present, the gold:silver ratio is less than 1, with silver averaging 17 ppm.

Bismuth averages 20 ppm but may reach several hundred ppm in areas with higher gold values. Nickel and cobalt values normally range from 100 to 200 ppm but both locally exceed 2 per cent in areas containing abundant visible erythrite and high gold values. Copper commonly exceeds 0.5 per cent over intervals of several metres, particularly in the sulphide-rich Bulldog zone. Secondary gold enrichment is also present in some weathered, near surface, oxide-rich zones and along certain faults. The resulting red hematitic clay zones may carry gold grading over 34 grams per tonne.

GEOLOGY AND GEOCHEMISTRY OF THE HEDLEY INTRUSIONS

The Hedley intrusions occur as narrow dykes and sills that may form dense swarms, and larger stocks exceeding 1 kilometre in diameter. The stocks are widely scattered throughout the district; they include the Pettigrew, Aberdeen and Larcan stocks, which are subcircular in shape, as well as the Banbury, Toronto, and Stemwinder stocks which are elongate along westerly to northwesterly trending lineaments (Figure 1-5-1).

In addition to their larger dimensions, the stocks are texturally and compositionally distinct from the dykes and sills and are economically less important. The stocks tend to be equigranular and of variable composition; in addition to diorite, quartz diorite and gabbro, they include large amounts of biotite and hornblende granodiorite. These granodiorite components are indistinguishable from the rocks in the younger Cahill Creek pluton and Bromley batholith and locally the margins of the pluton and batholith are dioritic and resemble the Hedley intrusions. This suggests that the older Hedley intrusions and younger Cahill Creek pluton may be close together in age and possibly genetically related to one another. Two discordant zircon fractions collected from the Cahill Creek pluton during this survey give $^{207}Pb/^{206}Pb$ dates of 196 and 199 Ma respectively (P. van der Heyden, personal communication, 1986). The Hedley and Stemwinder formations, are *circa* 225 Ma, based on the Late Carnian–Early Norian conodont dating, which suggests that lithification, regional folding, emplacement of the Hedley intrusion and Cahill Creek pluton, and development of the auriferous skarns all occurred within a 25-million-year interval.

In contrast to the stocks, the Hedley dykes and sills tend to be porphyritic and of less variable composition, ranging from diorite to quartz diorite and minor gabbro. Also, unlike the stocks which are largely unaltered, a significant number of dyke and sill swarms are enveloped by varying amounts of calcic skarn alteration that may, in rare instances, carry gold mineralization. However, most of the Hedley dykes and sills are unaltered and the immediately adjacent sedimentary rocks show few signs of either skarn alteration or hornfelsing, other than narrow siliceous or bleached selvages generally a few centimetres in width. Many of these unaltered sills and dykes contain disseminated pyrite and pyrrhotite which is responsible for the characteristic rusty red-weathering appearance of these rocks.

The coarse primary phenocrysts in the sills and dykes include dark-coloured hornblende and minor augite as well as abundant crystals of compositionally zoned plagioclase. With increasing skarn alteration many sills become bleached and the primary ferromagnesian minerals are replaced by colourless augite and pale-coloured tremolite-actinolite (Dolmage and Brown, 1945).

TABLE 1-5-1
UNALTERED HEDLEY INTRUSIONS

Field No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O
50.00	54.21	0.79	19.20	9.25	0.17	4.49	9.90	2.69	0.83
61.00	60.45	0.46	17.12	5.72	0.12	2.55	6.41	3.48	1.67
52.00	54.29	0.83	19.53	8.11	0.15	3.24	9.16	3.12	0.93
60.00	56.81	0.60	17.50	7.03	0.12	3.81	7.98	3.03	1.64
62.00	54.08	0.68	18.35	8.77	0.17	4.03	9.25	2.91	1.11
63.00	62.71	0.36	18.24	3.31	0.07	1.94	6.71	3.68	2.03
64.00	52.94	0.65	19.89	7.93	0.15	4.04	10.15	3.40	1.24
65.00	59.48	0.53	17.86	6.41	0.11	2.51	6.66	3.28	2.00
66.00	53.27	0.72	19.02	8.75	0.16	3.93	9.12	3.10	1.35
67.00	50.82	0.65	20.24	8.39	0.17	4.18	10.30	2.90	0.75
68.00	59.46	0.51	17.99	5.83	0.13	2.88	7.24	3.72	2.01
69.00	54.27	0.64	19.33	7.66	0.17	3.27	9.19	3.20	1.55
70.00	49.13	0.80	20.18	9.07	0.16	5.09	11.46	2.55	1.17
71.00	55.92	0.58	18.41	7.27	0.14	3.13	8.14	3.22	1.66
72.00	54.85	0.65	18.72	8.08	0.15	3.54	8.73	3.06	1.65
73.A	57.68	0.67	18.60	7.91	0.15	3.10	8.23	3.22	1.80
60.00	57.24	0.62	18.01	7.13	0.13	3.86	8.04	3.04	1.65
73.B	55.38	0.66	18.61	8.05	0.15	3.06	8.00	3.21	1.78
130.00	54.01	0.68	18.39	8.74	0.15	4.44	8.93	2.66	1.21
131.00	54.60	0.66	18.79	8.32	0.13	4.18	8.14	2.81	1.53
156.00	54.83	0.67	18.81	7.98	0.14	4.83	8.00	3.20	0.64
157.00	55.56	0.66	18.71	7.53	0.16	4.16	7.13	3.28	1.37
158.00	53.33	0.56	19.24	8.19	0.14	4.45	9.47	2.77	1.17
159.00	55.61	0.61	18.38	7.35	0.12	3.69	8.12	2.91	1.00
161.00	54.12	0.65	18.22	8.32	0.14	4.10	8.32	2.72	1.01
162.00	53.36	0.68	18.57	7.31	0.12	4.23	8.32	2.77	1.10
163.00	54.13	0.62	17.55	6.64	0.09	3.99	6.48	4.79	2.13
164.00	56.38	0.58	18.37	6.29	0.10	3.41	7.10	4.06	1.01
218.00	54.31	0.61	18.29	6.01	0.07	3.83	7.45	3.34	2.08

TABLE 1-5-2
ALTERED HEDLEY INTRUSIONS (ENDOSKARN)

Field No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O
84.00	59.79	0.50	15.68	4.97	0.14	3.04	11.43	3.73	1.07
85.00	61.87	0.55	18.16	3.76	0.04	2.41	7.63	3.62	2.28
155.00	60.37	0.46	18.01	5.62	0.12	2.66	6.03	3.37	2.13
160.00	60.47	0.43	18.34	4.46	0.07	2.29	6.03	4.51	0.96
401.04	51.17	0.63	17.09	6.57	0.12	6.36	10.20	3.38	2.14
401.12	47.99	1.02	18.15	8.97	0.11	4.70	9.72	2.70	2.43
401.16	52.57	0.61	15.94	7.66	0.06	3.57	8.25	2.05	5.11
401.21	51.18	0.65	17.96	6.69	0.09	4.35	8.54	3.87	2.12
401.23	54.89	0.62	18.51	6.37	0.09	4.54	7.74	3.99	1.48
401.24	54.58	0.63	18.61	7.66	0.11	4.49	7.52	3.11	1.36
403.02	57.22	0.60	17.08	6.22	0.09	2.71	6.14	3.33	3.03
73.13	53.72	0.63	18.03	5.39	0.07	3.98	8.98	4.18	2.66
73.14	54.98	0.63	18.36	3.31	0.06	4.38	10.34	3.96	2.72
73.15	58.81	0.50	16.34	3.91	0.08	3.10	8.15	3.76	3.44
73.17	55.55	0.50	17.68	3.22	0.07	3.67	8.29	3.93	4.33
73.19	50.95	0.50	11.12	10.76	0.38	4.72	17.87	1.29	2.04
73.21	57.39	0.47	17.50	2.43	0.08	3.50	7.45	4.50	4.20
73.26	49.67	0.39	14.00	11.90	0.39	2.77	13.92	3.78	1.13
73.28	57.03	0.53	18.08	4.68	0.09	3.04	9.03	4.12	1.48
73.32	54.15	0.65	18.38	6.12	0.10	4.01	7.64	4.23	2.01
73.17	57.29	0.55	17.34	3.24	0.06	3.65	8.37	3.83	4.40
261.03	59.23	0.44	16.63	2.99	0.09	2.10	6.67	1.73	9.88
261.04	61.24	0.46	16.94	2.60	0.06	2.60	7.18	3.75	3.84
261.05	63.55	0.46	17.29	1.56	0.04	2.19	7.64	4.37	2.94
261.11	57.32	0.54	18.29	3.11	0.09	3.18	8.67	5.24	2.05
261.17	36.44	0.20	3.66	12.71	0.40	1.55	27.20	0.01	1.80
261.25	59.96	0.50	16.24	4.60	0.06	3.07	7.20	3.66	2.25
261.27	55.50	0.70	18.09	3.99	0.07	3.52	9.55	3.41	3.49

The temporal and genetic relationships between the stocks and the sills and dyke swarms are unknown. Most stocks are not spatially associated with sills and dykes; however, it is postulated (Billingsley and Hume, 1941; Dolmage and Brown, 1945) that the dykes and sills responsible for the Nickel Plate gold deposit emanated from the nearby Toronto stock.

Geochemical data on major oxides from unaltered and skarn-altered (endoskarn) Hedley intrusions are presented in Tables 1-5-1 and 1-5-2 respectively. The unaltered samples were collected from the Stemwinder stock and from dykes and sills throughout the district. The endoskarn samples were taken mainly from drill holes at the Nickel Plate mine and represent skarn-altered sills and dykes. No examples of altered stocks were collected.

Normative plots in Figure 1-5-4A, using data presented in Table 1-5-3, illustrate the relatively uniform quartz diorite composition of Hedley intrusions and the quartz monzodiorite composition of the Cahill Creek pluton. In contrast, the gold-skarn related intrusions in the Tillicum Mountain camp (Roberts and McClintock, 1984; Ray *et al.*, 1986b) are of different composition, ranging from quartz monzonite to quartz monzodiorite (Figure 1-5-4B).

Alkali-silica plots of the unaltered intrusions in the Hedley district (Figure 1-5-5A) demonstrate the subalkaline character of both the Hedley intrusions and the Cahill Creek pluton. For comparison, similar plots of the intrusive rocks associated with precious-metal skarns at Tillicum Mountain and some iron skarns in British Columbia are presented in Figures 1-5-5B and 1-5-5C respectively; these, like the

TABLE 1-5-3
CIPW NORMS OF UNALTERED HEDLEY INTRUSIONS

Field No.	50	61	52	60	62	63
Q	5.92	16.00	7.14	9.96	6.00	17.59
or	4.83	10.07	5.53	9.84	6.60	12.11
ab	22.41	30.04	26.56	26.02	24.78	31.43
an	37.31	26.71	36.79	29.76	33.96	27.53
di	9.08	4.68	7.35	8.48	10.05	4.77
hy	15.04	8.34	11.08	11.23	13.49	[illegible].04
mt	3.27	2.90	3.40	3.09	3.18	2.72
il	1.48	0.89	1.59	1.16	1.30	0.69
AN=	62.47	47.07	58.07	53.36	57.82	46.70

Field No.	64	65	66	67	68	69
Q	0.73	13.76	3.47	1.69	10.58	4.75
or	7.30	11.96	8.02	4.50	11.91	9.23
ab	28.65	28.07	26.38	24.93	31.54	27.26
an	35.23	28.45	34.21	40.66	26.53	34.06
di	12.21	4.09	9.29	9.24	7.70	9.75
hy	11.00	9.26	13.38	13.95	7.51	10.07
mt	3.10	2.98	3.24	3.17	2.92	3.13
il	1.23	1.02	1.38	1.25	0.97	.22
AN=	55.15	50.33	56.46	61.99	45.69	55.54

Field No.	70	71	72	73A	60	73B
Q	0.00	8.13	5.86	8.72	9.70	6.90
or	6.94	9.96	9.81	10.49	9.78	10.64
ab	21.65	27.66	26.03	26.87	25.79	27.45
an	40.33	31.37	32.67	30.58	30.72	31.47
di	13.66	7.91	8.95	8.00	7.55	7.15
hy	5.24	10.28	11.73	10.44	11.72	11.39
ol	6.64	0.00	0.00	0.00	0.00	0.00
mt	3.35	3.06	3.13	3.10	3.08	3.17
il	1.53	1.12	1.24	1.26	1.18	1.27
AN=	65.07	53.14	55.65	53.23	54.37	53.41

Field No.	130	131	156	157	158	159
Q	6.58	6.72	7.35	7.70	4.58	10.76
or	7.21	9.12	3.82	8.21	6.96	6.04
ab	22.68	23.97	27.31	28.15	23.59	25.17
an	34.95	34.44	35.40	32.77	36.87	34.92
di	7.95	5.14	3.78	2.54	8.53	5.12
hy	15.51	15.59	17.32	15.66	14.80	13.16
mt	3.19	3.16	3.17	3.18	3.01	3.13
il	1.30	1.26	1.28	1.27	1.07	.13
AN=	60.65	58.96	56.45	53.79	60.98	58.11

Field No.	161	162	163	164	218
Q	8.72	7.94	0.00	8.18	5.53
or	6.12	6.74	13.05	6.13	12.80
ab	23.57	24.29	42.02	35.30	29.43
an	35.39	36.29	20.86	29.74	29.99
di	5.66	5.28	10.10	5.24	6.85
hy	15.48	14.34	5.58	10.77	10.62
ol	0.00	0.00	3.53	0.00	0.00
mt	3.19	3.28	3.19	3.10	3.19
il	1.26	1.34	1.22	1.13	1.21
AN=	60.02	59.90	33.17	45.72	50.47

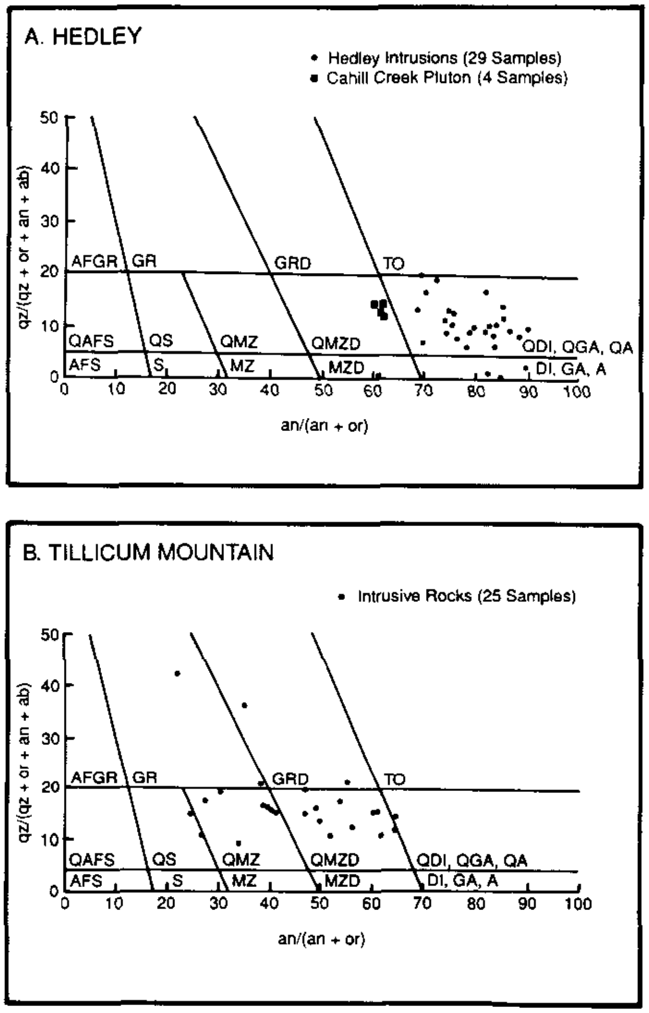

Figure 1-5-4. Chemical composition of plutonic rocks plotted on normative diagram of Streckeisen and Lemaitre (1979): A = Hedley; B = Tillicum Mountain (unpublished data from Ray); qz = quartz, or = orthoclase, an = anorthite, ab = albite, AF = alkali feldspar, S = syenite, MZ = monzonite, MZD = monzodiorite, DI = diorite, GA = gabbro, A = anorthosite, GR = granite, GRD = granodiorite, TO = tonalite.

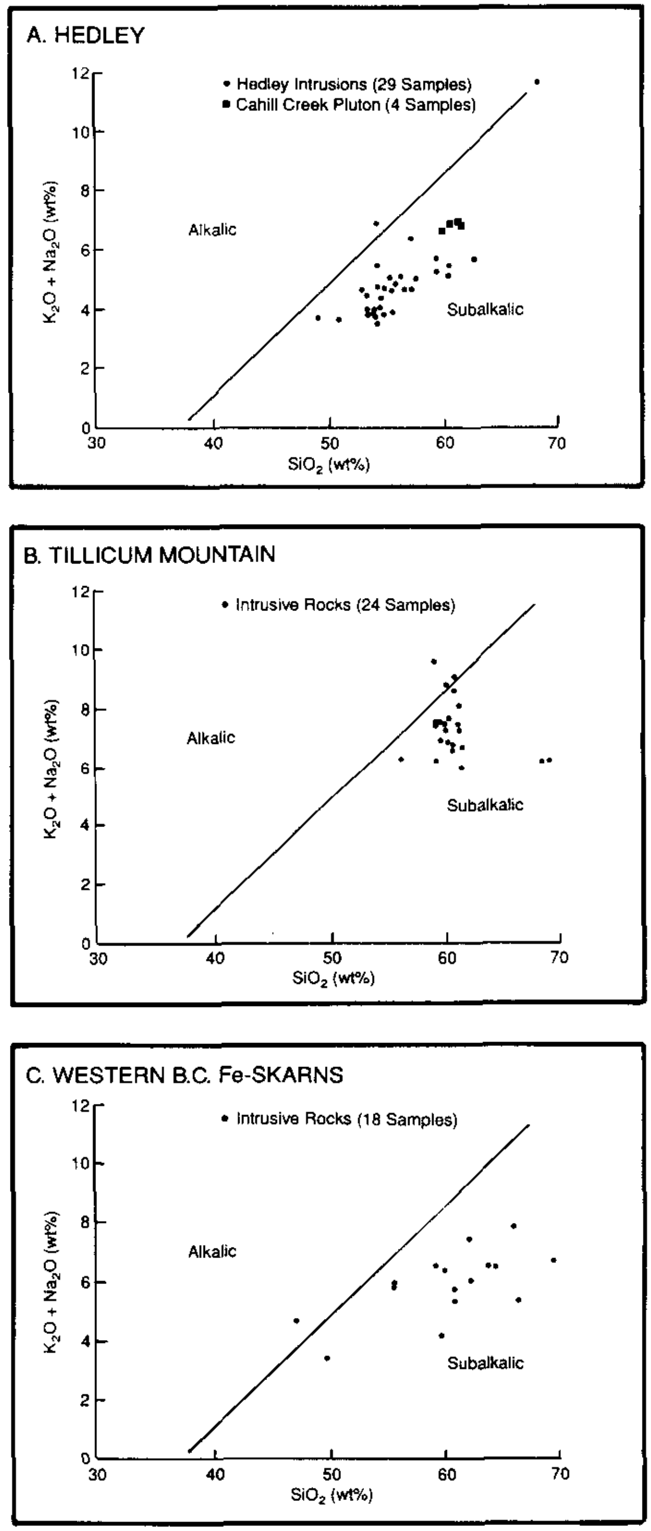

Figure 1-5-5. Alkalis versus silica plot (after MacDonald, 1968): A = Hedley; B = Tillicum Mountain (unpublished data from Ray); C = Western B.C. iron skarns (data from Sangster, 1969; Meinert, 1984).

Hedley intrusions, are subalkaline in character. AFM plots for these various intrusive rocks (Figures 1-5-6A, 1-5-6B and 1-5-6C) illustrate their common calcalkaline composition.

Figures 1-5-7A and 1-5-7B compare alkali-silica plots of the unaltered, skarn-related intrusions at Hedley with those at Tillicum Mountain. The relevant compositional fields for iron, copper and tungsten-skarn-related intrusive rocks, as determined by Meinert (1983), are also outlined. The Hedley intrusions fall largely within the iron-skarn field (Figure 1-5-7A) even though it is clear from both mineralogical and geochemical evidence that the Hedley skarns are not true iron skarns. By contrast, the Tillicum Mountain rocks fall largely within the copper-skarn field (Figure 1-5-7B) although the Tillicum Mountain gold skarns are not copper rich (Ray *et al.*, 1986b). It appears that gold skarns cannot be satisfactorily classified or differentiated using the base metal skarn plot of Meinert (1983), although the geochemical data do suggest that gold skarns are possibly related to, and found in the same geological regimes, as iron and copper skarns.

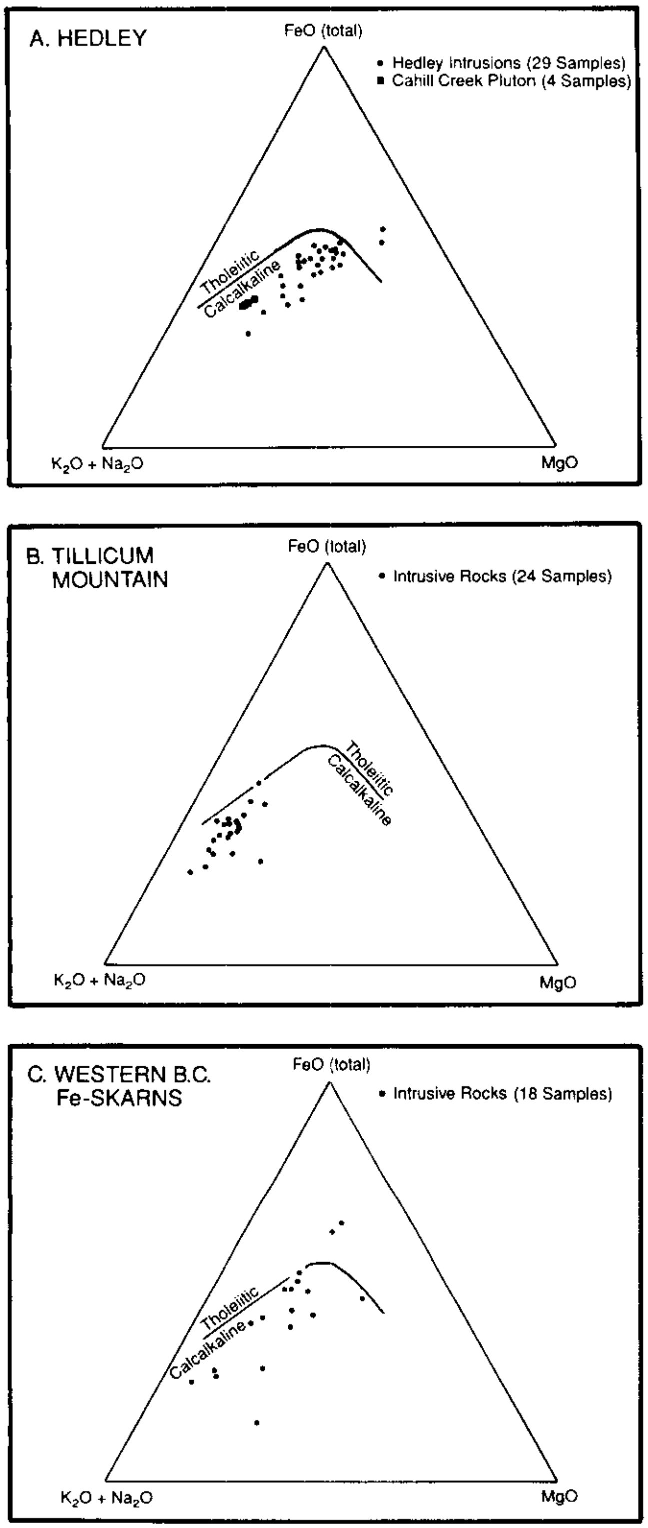

Figure 1-5-6. AFM diagram (after Irvine and Baragar, 1971) showing the calcalkaline trends of the intrusive rocks from three skarn camps: A = Hedley; B = Tillicum Mountain (unpublished data from Ray); C = Western B.C. iron skarns (data from Sangster, 1969; Meinert, 1984).

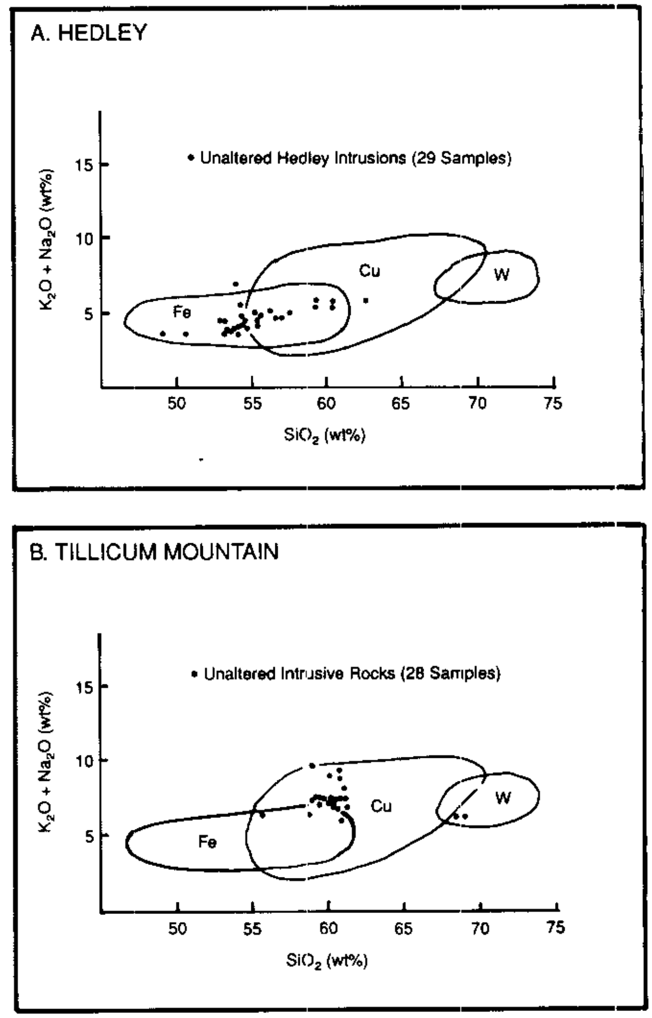

Figure 1-5-7. Alkali versus silica plot comparing skarn-related intrusive rocks at A. Hedley and B. Tillicum Mountain (unpublished data from Ray); skarn class boundaries modified after Meinert, 1983.

MINERALOGICAL ZONING IN THE SKARNS

Skarn and skarn-related alteration containing pyroxene-garnet assemblages are common and widely distributed in Nicola Group rocks throughout the Hedley district. Alteration varies considerably in grain size, intensity and extent; it ranges from narrow veinlets or irregular patches only centimetres or metres in diameter, up to huge alteration envelopes several hundred metres thick, such as that associated with the Nickel Plate deposit (Figure 1-5-8).

On an outcrop scale, a consistent concentric zoning of gangue mineralogy is recognized which is described by Ray *et al.* (1987). These small-scale zones are commonly the result of reaction between carbonate-rich beds and the skarn-forming fluids and range from the inner, coarse-grained, more intensely altered skarn assemblages, to the outer, finer grained margins of the envelope. In the ideal form the alteration zones initially develop along fractures adjacent to carbo-

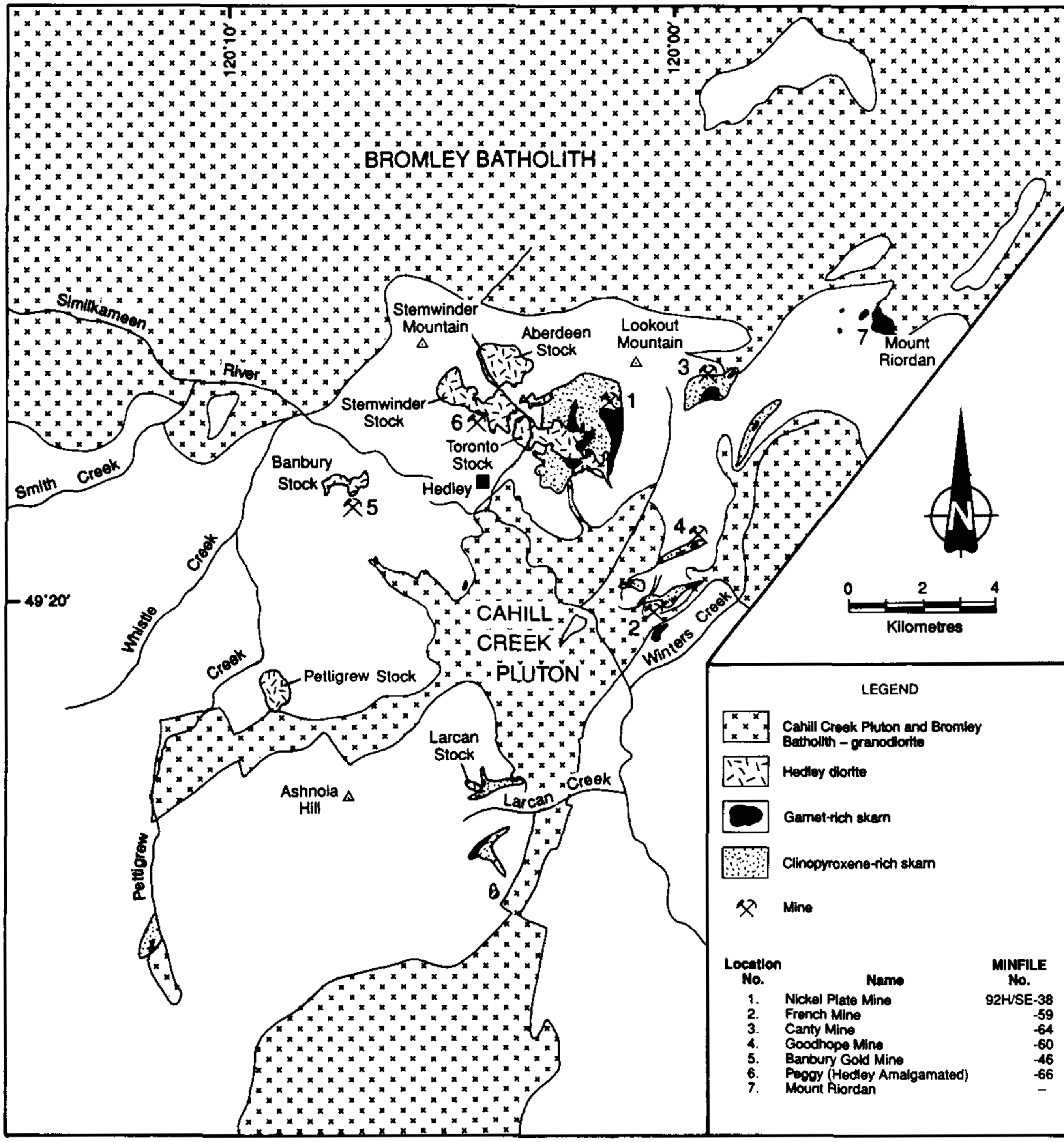

Figure 1-5-8. Areas of major skarn development in the Hedley district.

nate-rich beds or marble clasts. A central carbonate-rich core is commonly surrounded by a pinkish brown, garnet-rich section which passes outwards across a sharp contact to a green-coloured, generally wider, clinopyroxene-rich section. The clinopyroxene-rich zone may be separable into an inner, dark green, coarser grained assemblage and an outer pale green, siliceous, finer grained portion consisting largely of fine-grained clinopyroxene and quartz. The clinopyroxene-rich zone may pass outwards to a narrow section containing pink potassium feldspar and quartz. This potassium feldspar zone is often only a few centimetres thick and is absent in many outcrops.

The outermost alteration zone is of variable thickness and characteristically comprises a dark brown, siliceous, massive and fine-grained biotite hornfels. Contacts between the inner clinopyroxene-rich and outermost biotite hornfels zones are generally sharp, except where they are separated by thin reaction zones containing potassium feldspar and

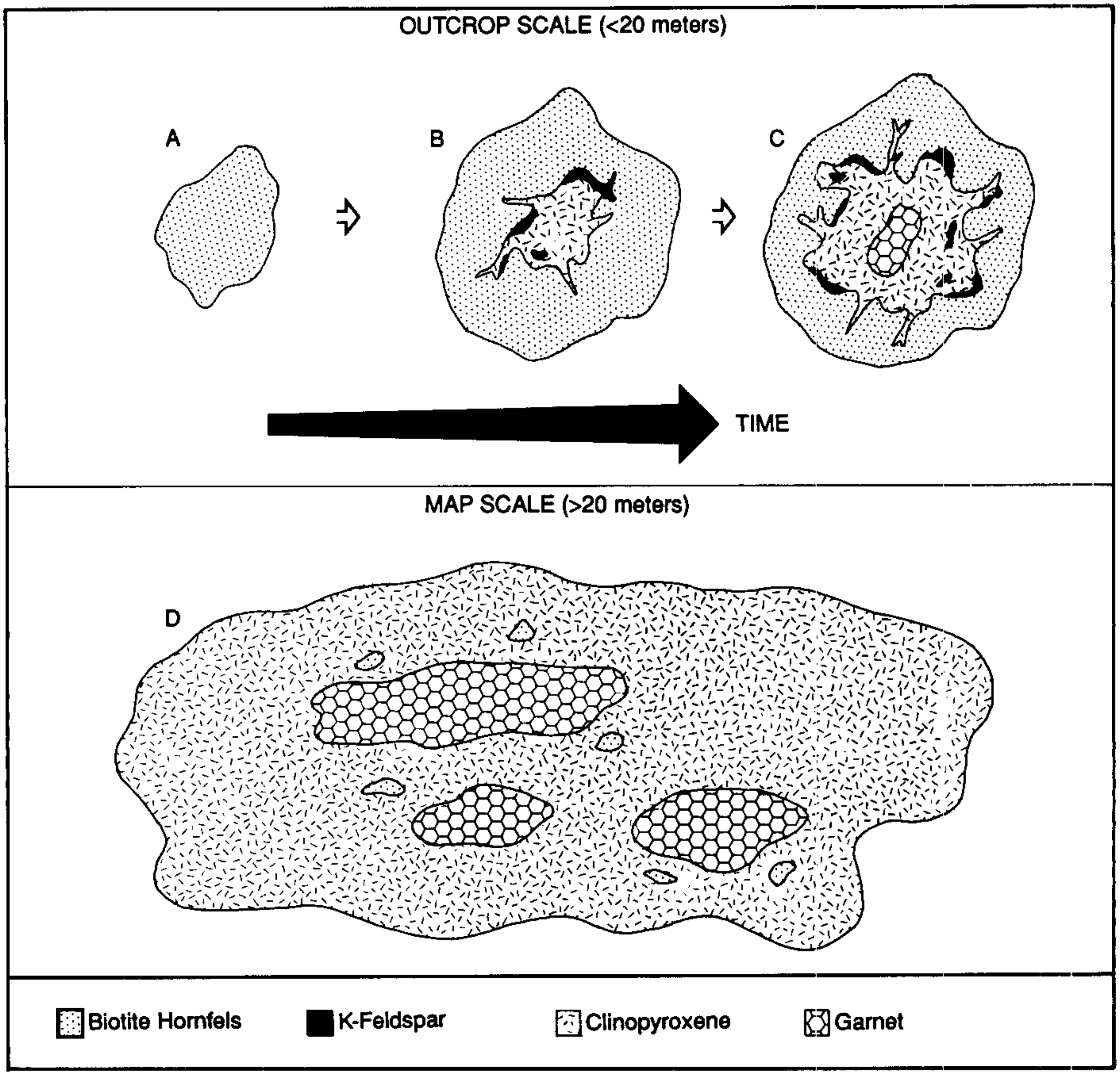

Figure 1-5-9. Progressive development of mineralogical zones in the Hedley gold skarns.

quartz. The outermost biotite hornfels is commonly cut by a network of thin, light-coloured veinlets of pyroxene and minor amphibole. These fine-grained pyroxene-rich veinlets may be irregular, but in many outcrops they show a preferred orientation and have followed pre-existing microfractures.

A temporal sequence of skarn development is recognized in the Hedley district and is illustrated in Figure 1-5-9. Initiation of the skarn process on a small scale commenced with formation of the siliceous biotite hornfels as an irregular patch of alteration (Figure 1-5-9A) often centred about a bedding plane fracture or crosscutting fault. It is emphasized that this hornfels alteration is **not** a thermal metamorphic feature related to the intrusion of the Hedley sills and dykes, but represents the preliminary stage of the skarning process and results from passage of the early, very hot, skarn-forming fluids along pre-existing fractures. Locally, some Hedley intrusions are also overprinted by the biotite hornfels-type alteration which emphasizes the post-magmatic, rather than the syn-magmatic, nature of this alteraton. The initial fracture control suggests that parts of this early hornfels-type alteration did not form under isochemical conditions.

As skarn-forming fluids continued to pass through the sedimentary host rock, clinopyroxene-rich alteration began to develop and the surrounding biotite hornfels aureole grew slowly outward (Figure 1-5-9B). With time, the area affected by the clinopyoxene-rich alteration grew steadily larger and development of a central zone of garnet-rich alteration began (Figure 1-5-9C). The garnet-rich alteration, which also steadily expanded outward, always began within the pre-existing pyroxene-rich zone, developing either along a fracture or as a reaction rim adjacent to an original carbonate-rich sedimentary bed.

When the biotite hornfelsic aureole reached a certain diameter, which in some outcrops can be measured in tens of metres or less, its development either slowed or stopped. However, both the garnet-rich and pyroxene-rich alteration zones continued their steady growth until they overprinted and completely replaced the hornfelsic aureole. This replacement often resulted in the development of the thin reaction zones of pink potassium-feldspar and quartz that separate the pyroxene and biotite hornfelsic zones (Figures 1-5-9B and C). The larger skarn envelopes, in contrast to the outcrop-sized skarns, have no peripheral biotite hornfelsic aureoles and the pyroxene-rich alteration passes directly outward into unaltered host rocks. In many cases the envelope of pyroxene-rich alteration contains small, irregularly distributed remnants of the earlier biotite and potassium feldspar alteration (Figure 1-5-9D).

Most of the very fine-grained, pyroxene-rich alteration in the Hedley district resembles what some geologists call "calc-silicate hornfels". However, the fracture-controlled nature of the pyroxene alteration suggests that metasomatism occurred on a local scale and thus it is regarded as "skarn" *sensu lato*. Alteration of this type is particularly well developed within the hangingwall portions of the larger skarn envelopes. An example of this hangingwall alteration is the "upper siliceous beds" which lie above the Nickel Plate deposit and are characterized by very fine-grained clinopyroxene, quartz and occasional potassium feldspar replacement of the thin-bedded sedimentary rocks. The presence of similar widespread alteration elsewhere in the district, such as that currently being explored by Chevron Minerals Ltd. east of Ashnola Hill (L. Dick, personal communication, 1987), may mark the presence of major skarn systems at depth.

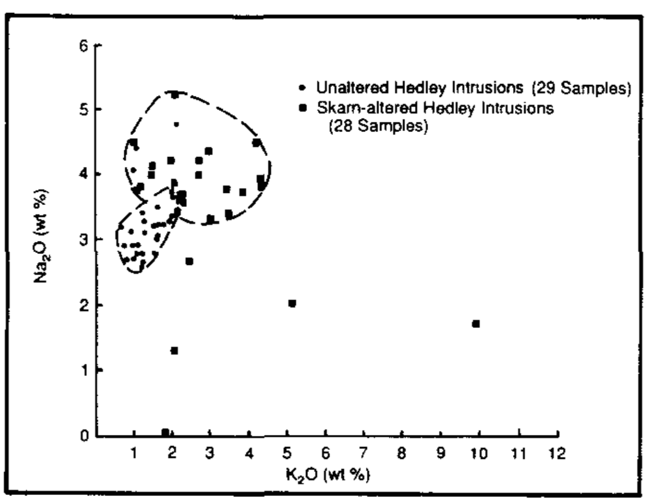

Figure 1-5-10. Plot of the Na_2O versus K_2O illustrating increases in sodium and potassium in skarn-altered Hedley intrusions compared to unaltered Hedley intrusions.

GEOCHEMICAL CHANGES ASSOCIATED WITH SKARN ALTERATION AND MINERALIZATION

Many previous workers, including Camsell (1910), Billingsley and Hume (1941) and Dolmage and Brown (1945), noted a spatial association between the Nickel Plate auriferous skarn mineralization and the Hedley intrusions, leading them to suggest a genetic relationship. Preliminary geochemical data presented in this report indirectly support this conclusion and suggest that the iron in the skarns was derived from the intrusions.

Data presented in Tables 1-5-1 and 1-5-2 demonstrate that many major elements including calcium, aluminum and titanium show little or no variation between the unaltered and skarn-altered dioritic Hedley intrusions. Some elements, however, notably total iron, and to a lesser extent silica, potassium and sodium, exhibit progressive compositional changes during the skarning process. Figure 1-5-10 shows that, compared to unaltered Hedley diorites, the skarn-altered (endoskarn) intrusions gain potassium and sodium. Likewise, Figure 1-5-11A illustrates that the skarning pro-

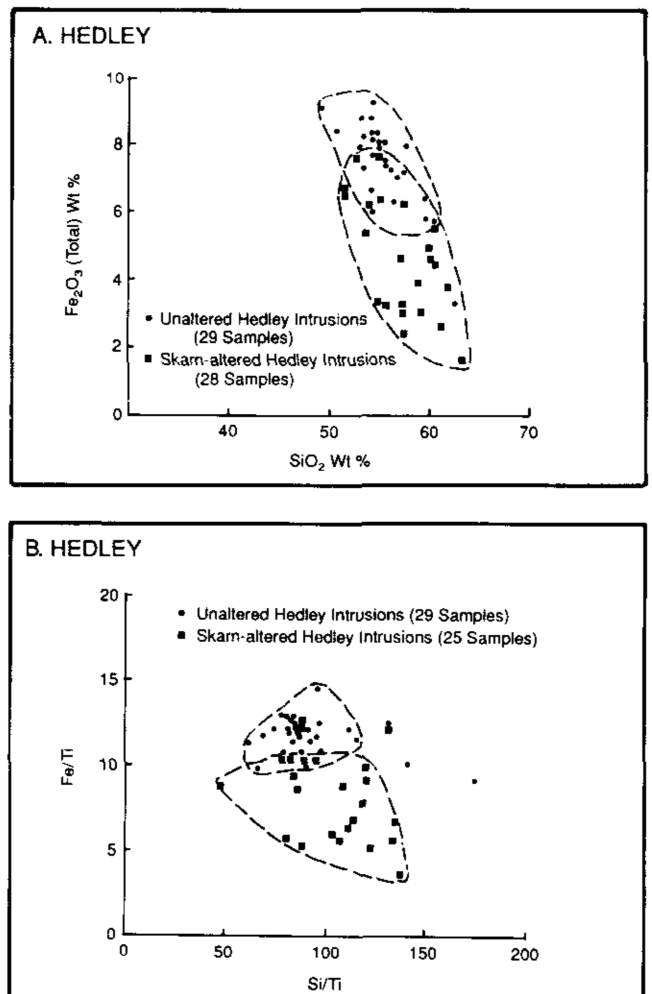

Figure 1-5-11. Comparing unaltered and skarn-altered Hedley intrusions; A = Fe_2O_3 (total) versus SiO_2 weight per cent; B = Fe/Ti versus Si/Ti.

cess results in a considerable loss of total iron and a modest gain in silica; this conclusion is supported by a plot of total iron/titanium against silica/titanium (Figure 1-5-11B). The genetic implications of this iron loss are illustrated by Figure 1-5-12 which compares endoskarn and exoskarn samples from three drill holes that intersect different parts of the Nickel Plate deposit. All the samples collected from these holes exhibit varying degrees of skarn alteration; the endoskarn samples are dioritic Hedley intrusions while the exoskarn is largely represented by altered calcareous siltstones and limestones of the Hedley formation (Table 1-5-4). Note that DDH 401 was collared outside the open-pit perimeter and intersected barren, generally fine-grained pyroxene-rich skarn; DDH 73 intersected subeconomic skarn-hosted mineralization west of the open-pit boundary; while DDH 261 contained ore-grade skarn mineralization and was collared within the planned open-pit area (Figure 1-5-12A).

Within the barren intersection (Figure 1-5-12B) the two fields outlining the iron-silica contents of the exoskarn and endoskarn are relatively close together, and the endoskarn is the more iron-rich. By contrast, in the subeconomic and economic intersections (Figures 1-5-12C and 1-5-12D) the iron content of the exoskarn greatly exceeds that of the endoskarn. In these two holes the exoskarn shows a major increase in iron and decrease in silica, matched by a corresponding drop in iron and rise in the silica in the endoskarn.

To summarize, progressive skarn alteration of the Hedley diorite intrusions results in no change in the calcium content, a modest increase in the sodium, potassium and silica contents and a major decrease in total iron. The adjacent skarn-altered sedimentary rocks (exoskarns) are correspondingly enriched in iron and depleted in silica. These preliminary results suggest three things. First, that relatively few metasomatic geochemical changes took place in the outer parts of the Nickel Plate skarn envelope and that the most dramatic metasomatism occurs in the mineralized parts of the skarn where there was presumably greater fluid movement. Second, the Hedley intrusive dyke and sill swarm was the source of the iron enrichment in the adjacent exoskarn, and thus may

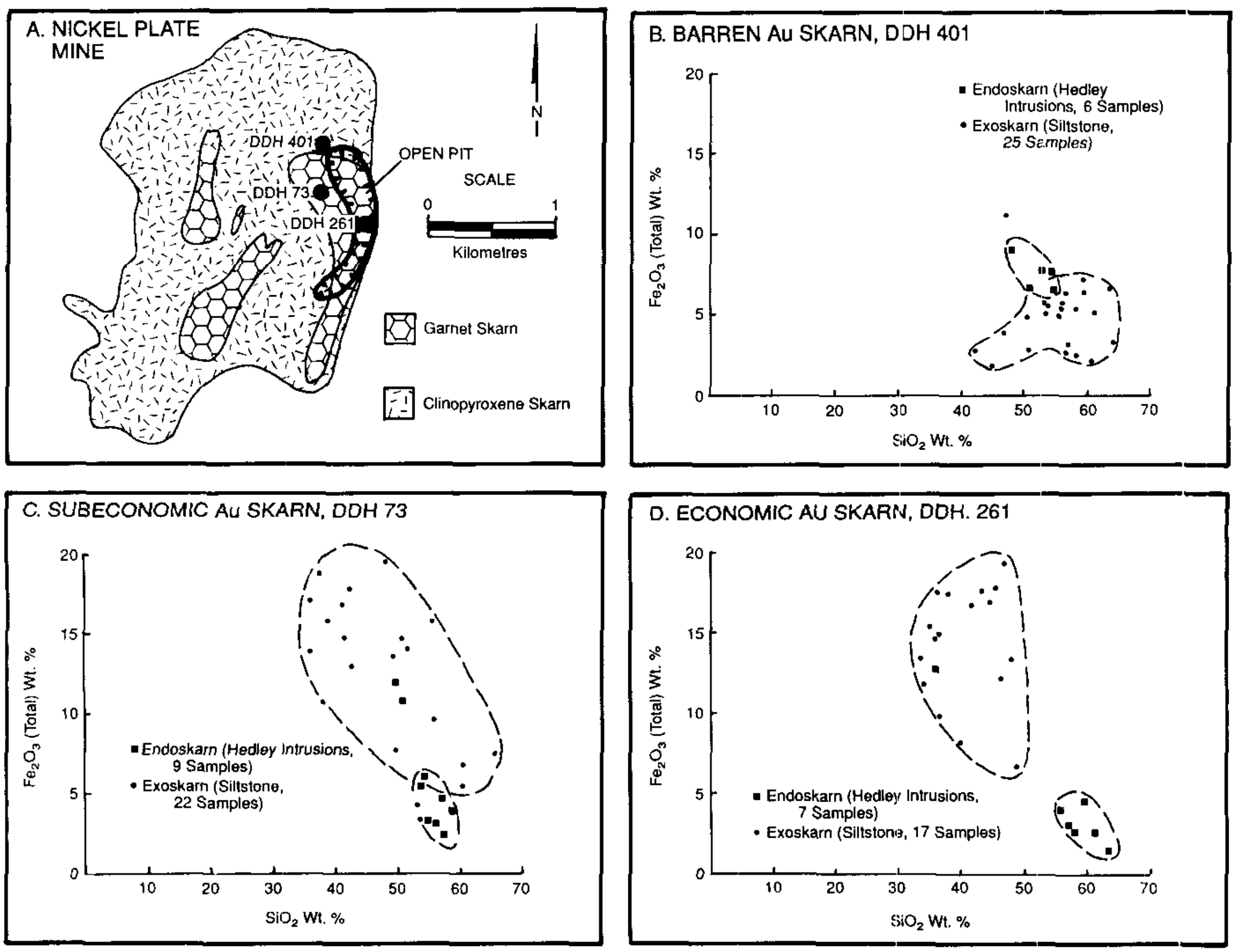

Figure 1-5-12. Plot of Fe_2O_3 (total) weight per cent versus SiO_2 weight per cent comparing barren, subeconomic and economic skarn from three diamond-drill holes at Nickel Plate mine: A = Nickel Plate mine showing location of drill holes in relation to the open pit and skarn zone; B = barren skarn, DDH 401; C = subeconomic skarn, DDH 73; D = economic skarn, DDH 261. Note: passage from barren to auriferous skarn is accompanied by a decrease in iron in the endoskarn Hedley intrusions and a corresponding increase in iron in the exoskarn sedimentary rocks.

TABLE 1-5-4
SKARN-ALTERED HEDLEY FORMATION (EXOSKARN)

Field No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O
401.01	47.27	0.51	8.77	11.14	0.20	6.40	17.92	0.00	3.18
401.02	58.17	0.57	16.06	2.56	0.08	3.46	6.91	2.19	7.11
401.03	53.36	0.73	15.21	5.69	0.16	4.75	13.38	1.87	3.30
401.05	56.59	0.66	17.04	6.35	0.13	3.33	7.26	3.91	3.14
401.06	57.97	0.63	16.18	5.42	0.08	3.98	6.59	4.12	1.90
401.07	53.68	0.55	13.21	5.55	0.18	4.17	11.52	1.18	5.66
401.08	55.75	0.58	13.82	5.49	0.13	3.48	10.25	0.51	7.72
401.09	55.97	0.54	14.38	5.79	0.12	2.94	8.69	0.61	8.60
401.10	53.45	0.47	14.41	5.11	0.12	3.08	10.42	0.87	7.63
401.11	56.56	0.66	17.75	2.69	0.07	2.76	8.48	3.43	4.97
401.13	58.36	0.59	15.67	3.75	0.10	4.03	8.12	2.42	5.76
401.14	55.28	0.67	18.00	4.80	0.07	4.89	9.57	4.24	1.29
401.15	56.83	0.74	17.23	3.26	0.07	4.27	10.27	2.85	3.76
401.17	51.04	0.68	16.81	6.52	0.11	5.85	14.91	2.89	0.23
401.18	55.88	0.60	16.83	5.52	0.07	3.82	7.11	2.52	4.65
401.19	59.19	0.87	12.62	7.12	0.08	4.05	6.03	1.54	4.67
401.20	63.42	0.86	13.06	6.65	0.07	3.30	4.16	1.80	5.05
401.22	42.02	0.23	4.59	2.77	0.19	3.80	27.62	0.00	1.04
401.25	63.95	0.33	6.12	3.29	0.12	3.20	11.24	0.12	3.82
401.26	59.20	0.90	17.93	6.42	0.12	2.15	4.44	3.14	3.11
401.27	44.77	0.20	4.89	1.84	0.06	2.59	27.73	0.71	0.85
401.28	60.54	0.25	4.99	2.21	0.06	3.85	15.91	0.65	1.04
401.29	50.80	0.32	6.41	2.77	0.05	2.71	18.62	0.81	1.54
401.31	61.06	0.41	8.66	5.15	0.09	3.57	9.50	0.55	4.63
401.32	46.68	0.28	6.17	3.88	0.10	7.50	24.21	0.48	1.62
73.01	60.52	0.77	11.36	5.40	0.15	3.46	8.84	1.39	6.76
73.02	52.11	0.57	7.89	12.43	0.34	4.79	16.36	1.93	2.48
73.03	42.80	0.52	10.71	12.93	0.48	3.78	25.68	0.75	0.67
73.04	41.61	0.42	9.01	14.65	0.46	2.48	28.04	0.07	0.54
73.05	38.89	0.34	7.10	15.80	0.42	2.32	31.25	0.02	0.01
73.06	41.25	0.39	6.01	16.81	0.51	2.73	28.42	0.06	0.02
73.07	65.68	0.29	5.43	7.48	0.25	4.44	11.80	0.23	3.95
73.08	51.53	0.30	7.20	14.08	0.50	3.60	17.37	0.55	3.99
73.09	53.58	0.65	18.03	3.45	0.12	4.21	12.79	2.02	4.02
73.10	49.63	0.88	19.24	7.73	0.18	4.15	9.74	1.22	4.55
73.11	60.44	0.37	8.53	6.78	0.24	2.36	13.51	0.94	3.66
73.12	50.70	0.30	4.99	14.68	0.63	4.99	20.96	0.76	2.01
73.16	49.21	0.28	7.92	13.58	0.52	2.21	21.79	0.71	2.91
73.18	55.62	0.32	0.44	15.78	0.73	4.17	12.95	1.22	0.84
73.20	55.71	0.47	9.01	9.56	0.41	3.56	13.55	0.49	6.10
73.22	38.16	0.35	9.78	10.79	0.56	2.94	30.51	0.38	0.35
73.23	37.39	0.13	5.65	18.67	0.34	1.67	31.73	0.03	0.01
73.24	42.48	0.22	6.15	17.77	0.62	2.55	27.77	0.02	0.01
73.25	36.07	0.15	6.73	17.08	0.43	1.28	30.28	0.01	0.01
73.27	48.19	0.46	2.95	19.48	0.79	4.04	22.38	0.29	0.80
73.29	36.16	0.30	5.07	13.90	0.45	2.39	27.35	0.63	0.88
73.30	53.18	0.29	5.73	4.26	0.11	3.13	23.65	0.89	1.06
261.01	38.10	0.27	8.03	17.46	0.37	1.31	32.43	0.06	0.05
261.02	36.66	0.13	9.26	14.88	0.32	0.44	33.73	0.05	0.80
261.06	41.61	0.57	5.71	16.79	0.60	2.36	28.61	0.04	0.02
261.07	36.42	0.16	7.16	17.53	0.27	0.77	34.20	0.01	0.33
261.08	35.06	0.18	7.63	15.27	0.29	0.84	34.27	0.01	0.71
261.09	46.28	0.17	2.77	12.20	0.47	1.94	27.04	0.01	0.64
261.10	34.14	0.33	3.99	11.90	0.48	2.02	31.83	0.41	0.93
261.12	43.23	0.36	7.19	17.64	0.61	2.13	26.13	0.06	1.27
261.13	45.36	0.20	3.65	17.85	0.76	3.88	23.94	0.14	0.60
261.14	46.86	0.37	4.19	19.42	0.74	4.12	22.75	0.31	0.45
261.15	33.82	0.11	2.23	13.43	0.46	1.57	26.89	0.01	0.81
261.16	35.99	0.26	6.91	14.60	0.35	2.20	21.83	0.22	2.47
261.18	47.90	0.26	5.42	13.41	0.35	2.40	20.52	0.27	1.26
261.19	44.46	0.41	6.39	16.97	0.35	2.91	16.44	0.21	2.54
261.20	36.67	0.27	5.15	9.84	0.35	2.67	27.16	0.01	1.10
261.21	48.82	0.22	4.64	6.72	0.22	1.53	22.51	0.01	1.50
261.22	39.84	0.41	6.39	8.13	0.22	3.46	23.71	0.12	3.09

also be the primary source of the skarn-hosted gold. Third, outlining areas containing iron-enriched exoskarn adjacent to iron-depleted endoskarn may provide a useful exploration tool for recognizing close proximity to auriferous skarn mineralization in the Hedley district.

GEOLOGY OF THE MOUNT RIORDAN TUNGSTEN-COPPER SKARN

During this study interesting tungsten-copper skarn mineralization was outlined within and adjacent to several Crown-granted mineral claims on Mount Riordan, approximately 7 kilometres east-northeast of the Nickel Plate mine (Figures 1-5-1 and 1-5-8). Although there are numerous old prospect pits on Mount Riordan, it was uncertain at first whether the scheelite mineralization had been recognized by the earlier workers, particularly since there was no evidence of past drilling and the mineralization was not listed in the Ministry of Energy, Mines and Petroleum Resources' MINFILE. Subsequent literature search indicated that the Mount Riordan occurrences were briefly described by McCammon (1953), although the mineralization was largely ignored by industry, even throughout the tungsten boom of the 1970s. W.J. Bromley (personal communication, 1987) indicates that some bulk sampling was undertaken in the 1950s, but since that time little exploration has taken place.

The outcrop geology of the Mount Riordan area is shown on Figure 1-5-13. A massive, fresh biotite hornblende granodiorite, that is characterized by coarse hornblende phenocrysts and sparse pyrite, outcrops to the northeast and east of the mountain. To the south, and presumably separated from the rocks on Mount Riordan by an east-northeastly trending fault, are the highly deformed ophiolitic rocks of the Apex Mountain complex. A very large elongate mass of mainly garnetite skarn, which reaches 900 metres in length and 500 metres in maximum width, is centred on Mount Riordan. The surrounding rocks are mostly obscured by glacial overburden, but to the west are several small exposures of skarn and one of massive, coarse-grained marble (Figure 1-5-13). South of the summit, within the skarn, are minor remnants of altered microdiorite, while the extreme eastern edge of the skarn is in contact with altered epidote-veined outcrops of hornblende-porphyritic granodiorite similar to that occurring further northeast.

Apart from rare marble remnants, the nature of the protolith to the Mount Riordan skarn is uncertain; alteration is also so complete and exposure so poor that the stratigraphic relationship between the protolith and the sequences recognized elsewhere in the district is uncertain, although it probably lies within the limestone-rich French Mine formation. The rare marble layers in the garnetite are flat to gently dipping.

The Mount Riordan skarn differs considerably in appearance from the Nickel Plate skarn and mainly comprises massive, coarsely crystalline andraditic garnetite; almost no original textures are recognizable. Unlike the gold-bearing skarns to the west, no mineralogical zoning or biotite-hornfels rocks have been seen within the Mount Riordan skarn. The garnets vary considerably in colour; black, red, pink, brown, green and yellow-green varieties are present. In a few cases the crystals exceed 6 centimetres in diameter and show prominent growth zonations. Some massive outcrops also display sharply defined, subparallel zones of different coloured garnetite and in one outcrop the pale-coloured garnetite matrix contains "clasts" of dark-coloured garnetite up to 1 metre long and 0.2 metre wide. These clasts have sharp contacts and it is uncertain whether they represent remnants of either an original conglomeratic texture, a tectonic bondinage feature, or the results of two different episodes of garnet growth.

Quartz and epidote together with variable amounts of carbonate, hedenbergite, clinopyroxene and actinolite, and traces of chlorite and wollastonite are also present in the garnetite. Some epidote forms coarse euhedral crystals. Locally, particularly near the summit of Mount Riordan, the skarn is cut by veins, blebs and stringers of either white quartz or coarely crystalline carbonate that may exceed 1 metre in width. In some veinlets, where the quartz and carbonate are intergrown, the quartz forms elongate, well-terminated crystals up to 3 centimetres in length.

Locally the skarn contains pockets, irregular veinlets and disseminations of magnetite intergrown with variable amounts of pyrrhotite, pyrite, chalcopyrite and trace bornite. Magnetite is present within and adjacent to a short adit on the eastern side of Mount Riordan and in the most westerly outcrop of skarn in the area (Figure 1-5-13). Generally the gold values in the skarn are very low (*see* Table 1-5-5); however, the highest assays (up to 1.69 ppm gold) are found in the magnetite-sulphide-rich portions of the skarn.

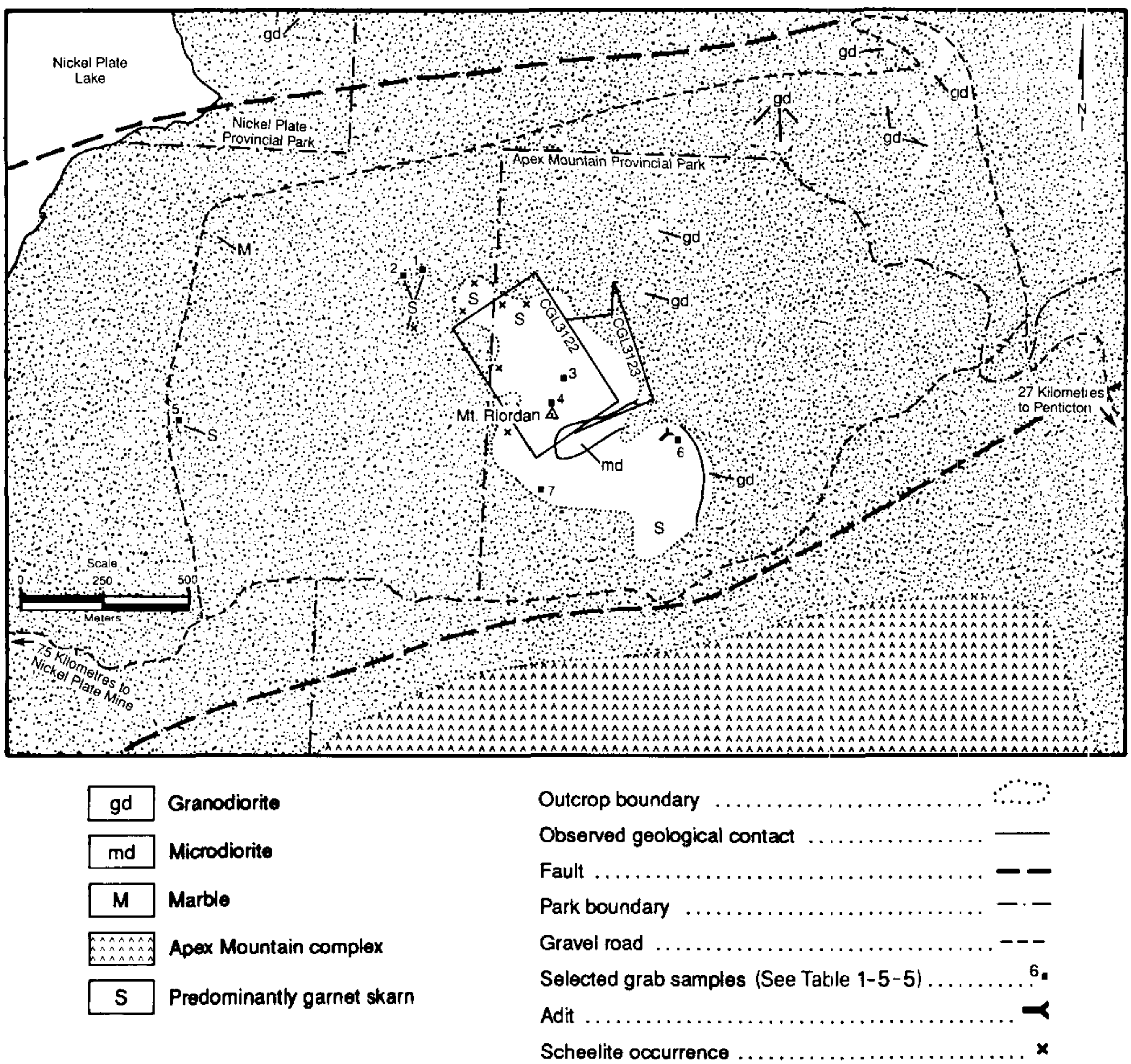

Figure 1-5-13. Outcrop geology of the Mount Riordan area. Note: for assay results of selected grab samples from locations 1 to 7 *see* Table 1-5-5.

TABLE 1-5-5.
ANALYSIS OF SELECTED GRAB SAMPLES FROM MOUNT RIORDAN

Location No.	Lab. No.	W%	Cu ppm	Mo ppm	Au ppb	Ag ppm	Zn ppm
1	33668	0.1	850	5	475	7	75
2	33666	0.25	840	15	339	0.8	210
3	33661	>5.0	600	250	187	0.7	105
3	33662	3.0	0.7%	106	<20	10	357
3	33663	0.1	0.3%	19	161	15	321
3	33664	0.5	0.2%	33	99	9	111
3	33665	0.35	75	310	498	0.5	270
3	33667	0.25	150	145	<20	0.5	258
3	33672	4.0	0.35%	152	122	5	106
3	33673	2.0	0.16%	36	37	1.3	50
4	33670	0.9	118	6	<20	0.6	159
4	33671	0.7	117	17	40	0.5	307
5	33669	0.1	45	5	<20	0.5	73
5	33674	0.1	84	30	<20	0.5	52
6	33676	<0.1	75	5	14	3	138
6	33677	<0.1	0.74%	7	1690	19	0.11%
7	33675	<0.1	0.13%	6	29	0.7	118

Note: W by semi-quantitative emmission spectrophotometry; Cu, Mo, Au, Ag and Zn by AAS analysis).

Visible traces of scheelite are seen over a wide area, both throughout the skarn and as minute detrital fragments in the soils. However, the best developed tungsten mineralization occurs close to the summit of the mountain where numerous old pits and trenches have been dug in an area of approximately 40 by 100 metres. In this area, where the garnet skarn contains abundant coarse quartz and/or carbonate veining and disseminated massive pyrite-pyrrhotite, it is extensively weathered to jarosite.

The scheelite occurs in two forms. The commonest and probably earliest is found as small crystals, generally less than 1 millimetre in diameter, sparsely disseminated or clustered in zones throughout the garnetite. The other, possibly later generation, forms spectacular blebs, coarse crystalline masses and irregular veinlets up to 5 centimetres wide and 300 centimetres in length. This coarser scheelite is usually associated with quartz and carbonate veining and in some instances both the quartz and carbonate enclose rounded masses of scheelite. The distribution of the coarse scheelite is generally irregular, however, in one trench the veinlets form an irregular stockwork. Some scheelite-rich outcrops may also contain minor amounts of powellite [$Ca(Mo,W)O_4$] although this has not been positively identified, together with coarse axinite. Analyses of various mineralized grab samples collected throughout the Mount Riordan skarn are listed in Table 1-5-5.

The age and origin of the Mount Riordan skarn is unknown and it is uncertain whether the microdiorite remnants within the skarn, and the porphyritic granodiorite further east, are related to the skarn alteration and tungsten-copper mineralization. However, epidote veining and alteration indicate that both these intrusions predate the skarn.

DISTRICT-WIDE METALLOGENIC ZONING IN THE HEDLEY DISTRICT

The location and distribution of areas underlain by major skarn alteration in the Hedley district are shown in Figure 1-5-8. All these areas lie within the central and eastern, more proximal facies, lime-rich supracrustal rocks, while skarns are only poorly developed in the deeper basinal facies to the west. The largest area of skarn alteration covers approximately 6 square kilometres and surrounds the Nickel Plate deposit. Other substantial alteration zones include those associated with the Canty, Goodhope and French mines, as well as areas east of Ashnola Hill and at Mount Riordan.

The auriferous deposits in the Hedley camp have formerly been regarded as relatively uniform gold (copper-cobalt-arsenic) skarn mineralization (Camsell, 1910; Billingsley and Hume, 1941, Ray *et al.*, 1987). However, the Mount Riordan skarn is distinct in being gold-poor, tungsten and copper-rich, and garnet-dominant in contrast to the pyroxene-dominant Nickel Plate skarn. The following possible relationships are considered:

(1) The Mount Riordan skarn is unrelated to the gold-rich skarns further west and their relatively close proximity is coincidental.

(2) The two skarn types are related and derived from a common basement source, but were emplaced at different, possibly widely separated times.

(3) The Mount Riordan skarn is temporally and genetically related to the Nickel Plate skarn and other gold skarns in the district.

The third alternative is tentatively favoured, partly because the mineralization and mineralogy in the vicinity of the French and Goodhope mines exhibit geochemical and mineralogical characteristics intermediate to the Mount Riordan and Nickel Plate skarns. For example, the Goodhope skarn contains crystalline, variably coloured garnet similar to Mount Riordan while other skarn occurrences close by are magnetite rich. Both the Goodhope and French mines locally contain abundant fine and coarse-grained scheelite together with the gold and copper. Underground chip sampling along a 35-metre, gold-rich skarn section at the French mine averaged 0.68 per cent WO_3 with maximum values of 1.32 per cent over 3 metres (Westervelt Engineering Ltd., unpublished report, January 12, 1978). Thus the Hedley camp probably possesses a district-wide metallogenic zoning with gold-rich, tungsten-poor skarns in the west through to tungsten-rich, gold and arsenic-poor skarns in the east. This has important implications elsewhere in the Cordillera, as some tungsten skarn districts, particularly those associated with fracture-related basin margins, may have gold skarn potential. The east-to-west metallogenic zoning is also accompanied by changes in skarn mineralogy, hostrock geology and composition of the skarn-related intrusions (Table 1-5-6). The skarns in the western and central parts of the district are clinopyroxene-rich and epidote-poor, while the Mount Riordan skarn is garnet and epidote-rich and clinopyroxene-poor. The nature and colour of the garnets also vary across the district; in the western skarns, including those at the Nickel Plate mine, they are generally poorly crystalline and uniformly pink to brown coloured, while at the Goodhope mine and Mount Riordan they are coarsely crystalline and highly variable in colour.

The composition of the skarn-related intrusions varies across the district from diorite at the Nickel Plate, Canty, Goodhope and French mines to possible granodiorite at

TABLE 1-5-6.
CHARACTERISTICS OF EAST–WEST SKARN VARIATION
ACROSS THE HEDLEY DISTRICT

FEATURES	WEST NICKEL PLATE MINE	FRENCH AND GOODHOPE MINES	EAST MOUNT RIORDAN
Skarn mineralogy	Banded, clinopyroxene-dominant skarn. Garnets – generally noncrystalline and brown	Locally clinopyroxene or garnet-dominant skarn. Crystalline and noncrystalline garnet	Massive, garnet-dominant skarn. Crystalline garnet with highly variable colour
Degree of skarn overprinting	Sedimentary structures often preserved in skarn	Sedimentary structures locally preserved	No sedimentary structures preserved
Skarn metallogeny	Au, As, Cu, Co, Bi, Te, Ag, Ni	Au, Cu, W, Co, Mo, Bi, As, Ag	W, Cu, Ag
Skarn-related intrusions	Associated with I-type dioritic Hedley intrusions	Associated with I-type dioritic Hedley intrusions	Associated with I-type granodiorites that do not resemble the Hedley intrusions
District hostrock geology	Siltstones and limestones of the Hedley formation	Limestone breccia and limy sediments of the French Mine formation	Probably massive limestone of the French Mine formation

Mount Riordan (Table 1-5-6). These variations in skarn mineralogy and intrusion composition probably reflect east-to-west changes in the basement rocks that underlie the Nicola Group which presumably represents the source of the skarn-related intrusions.

CONCLUSIONS ON THE HEDLEY DISTRICT

- The Upper Triassic Nicola Group rocks of the Hedley district contain a recognizable stratigraphic succession. At the bottom and top of this succession are volcaniclastic rocks of the Peachland Creek and Whistle Creek formations. Separating these tuffaceous sequences is a 100 to 700-metre sedimentary succession which paleocurrent indicators and facies changes suggest was deposited across the northeasterly trending, tectonically controlled margin of a northwesterly deepening, shallow marine basin. From east to west, the progressively thickening facies sequences are represented by the predominantly carbonate-bearing French mine, siltstone-dominant Hedley and argillite-dominant Stemwinder Mountain formations.
- The two main intrusive episodes in the district, the older dioritic Hedley intrusions and the younger granodioritic Cahill Creek pluton, may be genetically related and were emplaced shortly after one another during a folding episode. Intrusion took place post-225 Ma (the age of the hosting sedimentary rocks based on Carnian-Norian microfossils) and pre-200 Ma (the preliminary $^{207}Pb/^{206}Pb$ zircon date obtained from the Cahill Creek pluton).
- The Hedley intrusions are spatially associated with two contrasting but probably coeval types of gold mineralization. The first type is widespread, more economically significant and associated with deeper level contact metasomatic pyroxene-garnet-carbonate skarn alteration assemblages. The other type is more restricted, is less economically important and is associated with higher level, tension-fracture quartz-carbonate vein systems. The volume of skarn alteration developed throughout the district varies in scale from narrow, fracture-related halos only centimetres in thickness to huge alteration envelopes several hundred metres in width similar to that surrounding the Nickel Plate – Hedley Mascot deposit.
- A small-scale, consistent, concentric zoning of gangue mineralogy is present at many skarn outcrops and a temporal sequence of skarn alteration is recognized. On the small scale the initial skarn process involves development of a biotite hornfels-type alteration which may locally overprint both the sedimentary rocks and the Hedley intrusion sills. This is followed by the sequential development of pyroxene-rich followed by garnet-rich assemblages which, as the alteration envelope enlarges, eventually replace and obliterate the earlier biotite hornfelsic aureole. Replacement of the biotite aureole by the pyroxene alteration often results in development of a thin intervening reaction zone containing potassium feldspar. It is uncertain whether the potassium was introduced with the skarn-forming fluids or represents remobilized and concentrated potassium that was originally present in the sediments.
- The economic auriferous skarn mineralization is structurally, lithologically and stratigraphically controlled. The Hedley intrusion sills and dykes are more often associated with the skarn mineralization than the larger stocks. Economic gold values tend to be confined to the exoskarn

while the endoskarn is generally barren. Most of the auriferous skarns are confined to the shallower marine, limestone-bearing Hedley and French Mine formations and are more commonly developed in flat-lying or gently dipping beds. Other controlling features include sill-dyke intersections, fractured sill margins and small-scale fold hinges, as noted by Billingsley and Hume (1941) at the Nickel Plate mine, as well as close proximity to the Copperfield conglomerate, a limestone-boulder olistostrome which overlies the Hedley formation.

- Both the skarn-related Hedley intrusions and the Cahill Creek pluton represent I-type, calcalkaline intrusions. During the skarning process, the altered diorite sills (endoskarn) gain sodium, potassium and silica but undergo a considerable loss of total iron. Comparative whole-rock geochemistry suggests the Hedley intrusions are the source of the iron enrichment present in the exoskarns and may also be the source of the gold.

- The Nickel Plate gold deposit is hosted in calcareous and tuffaceous siltstones in the upper part of the Hedley formation. It is associated with a skarn envelope that exceeds 300 metres in thickness and 6 square kilometres in outcrop area. The gold-bearing and arsenopyrite-rich zones normally occur as semiconformable tabular bodies situated less than 100 metres from the outer and lower skarn margin. There is significant geochemical and mineralogical variation throughout the deposit and the gold and sulphide mineralization postdates the garnet-clinopyroxene-carbonate skarn alteration, although there is surprisingly little propyllitic alteration of the ferromagnesian minerals. Three stages of sulphide deposition took place, namely: (i) pyrite; (ii) arsenopyrite and gersdorffite; (iii) pyrrhotite, chalcopyrite and sphalerite. Gold, occurring as blebs less than 25 microns in diameter, was introduced with the latter two phases and is associated with the bismuth telluride, hedleyite. Statistically, gold shows a strong to moderate positive correlation with bismuth, cobalt and arsenic and a low correlation with silver and copper.

- The Hedley camp does not, as formerly believed, consist solely of uniform, gold-copper-arsenic-cobalt-enriched skarn mineralization. An east-to-west district-wide metallogenic zoning of the skarns may exist with gold-cobalt-arsenic-rich skarns occurring in the west (Nickel Plate) and tungsten-copper-magnetite-rich gold-poor skarns developing in the east (Mount Riordan). Mineralization in the central part of the district (French and Goodhope mines) has some intermediate mineralogic and metallogenic characteristics. The metallogenic zoning, which also parallels changes in the original geological environment (deeper basinal in the west, shallower marine to the east) probably reflects east-to-west changes in the composition of the basement rocks which underlay the Nicola Group and controlled the Late Triassic basin margin. This suggests that some tungsten skarn camps in the North American Cordillera, particularly those developed along fracture-controlled, island arc-related marine-basin margins, could have the potential for gold-skarn mineralization similar to the Nickel Plate deposit.

GENERAL CONCLUSIONS ON GOLD SKARNS

A comparison between the gold skarns at Tillicum Mountain (Ray *et al.*, 1986b), Texada Island and the OKA property (Ettlinger and Ray, 1988, this volume) and Hedley suggests the following features:

- All are hosted in island-arc sequences that include limy sediments and either volcanic or volcaniclastic rocks of andesitic to basaltic composition. Regionally, the volcanic rocks at Tillicum Mountain (Rossland Group), Hedley and OKA (Nicola Group) include potassium-rich shoshonites.

- Fault-controlled marine-basin margins may have good exploration potential for gold skarns because:
  (a) They often contain sedimentary lithologies (calcareous sediments, limestone boulder conglomerates) suitable for skarn development.
  (b) The deep basement structures localize intrusive activity that may result in auriferous skarn formation.

- Gold in skarn varies from very coarse grained and visible (Tillicum Mountain) to micron sized (Hedley).

- To date, all of the gold skarns studied in British Columbia are associated with calcalkaline I-type intrusions and it is not known whether there are any gold skarns in the province related to alkalic rocks. However, some alkalic, high-level intrusions in the Nicola Group are associated with a class of gold-bearing porphyry copper deposit, such as Copper Mountain (Fahrni *et al.*, 1976) and Cariboo-Bell (Hodgson *et al.*, 1976) that locally contain some garnet-pyroxene-epidote-scapolite skarn-like alteration features.

- The Hedley, Tillicum Mountain and OKA areas involved similar intrusive sequences characterized by early skarn-related intrusions of generally small volume and dioritic to gabbroic composition, followed by large amounts of barren granodioritic material forming major batholiths which enclose the skarn-hosting sequences and leave them as roof pendants. Preliminary dating suggests these two sequences at Hedley (the Hedley intrusions and the Cahill Creek pluton) are close together in age; it is possible that they are related and originated from the same magma source.

- At the Hedley, Tillicum Mountain and Texada Island gold camps there are suggestions that the skarns are metallogenically zoned on a district scale. Metallogenic zoning is also reported at some other skarns such as the large Fortitude deposit in Nevada (G. Myers and A. Ettlinger, personal communication, 1988). However, the Hedley area is believed to be the first major skarn camp in which gold-to-tungsten zoning is recognized.

- There is a highly variable trace element association with the gold in gold skarns. Some are enriched in cobalt, arsenic, antimony, tellurium, bismuth, molybdenum, tungsten and copper. Some, such as those in the Hedley camp, contain most or all of these elements, while in others these elements may be absent. At present no general rule can be made concerning trace element enrichment in gold skarns.

- The amount of skarn alteration associated with gold mineralization varies considerably from the narrow alteration envelopes present at Texada Island, Tillicum Mountain and the OKA properties, up to the immense volumes of alteration developed in the Hedley camp. Generally, the amount of skarn alteration developed appears to be proportional to the amount of gold present in the system. Thus, large tonnage gold deposits are more likely to be found in areas containing large skarn alteration envelopes.

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