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THE GEOLOGY AND CONTROLS OF SKARN MINERALIZATION IN THE HEDLEY GOLD CAMP SOUTHERN BRITISH COLUMBIA* (92H/8, 82E/5)

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INTRODUCTION

The current Hedley mapping project by the Ministry of Energy, Mines and Petroleum Resources is part of the joint Canada/British Columbia Mineral Development Agreement program. The objectives of the program are fully outlined by Ray *et al.* (1986), and include district-wide geological mapping at a field base map scale of 1:15 000.

The Hedley gold camp is situated approximately 40 kilometres east-southeast of Princeton, in southern British Columbia. The area has had a long history of gold mining and between 1902 and 1955 approximately 51 million grams (1.6 million ounces) of gold were won from several mineralized skarn orebodies (Table 2-10-1). Most production came from the Nickel Plate and Hedley Mascot mines (Mineral Inventory 92H/SE-038 and 036) located south of Lookout Mountain (Figure 2-10-1); total production from the smaller French, Canty, Good Hope and Banbury mines (MI 92H/SE-059, 064, 060 and 046 respectively) was approximately 1.8 million grams of gold (Table 2-10-1). Mineralization is also seen at the Peggy (Hedley Amalgamated) and Gold Hill properties (MI 92H/SE-066 and 054) (Figure 2-10-1).

The Hedley district was geologically mapped more than 40 years ago (Camsell, 1910; Bostock, 1930, 1940a, 1940b) but since that time little regional geological work has been done. The areas immediately surrounding some of the gold producers were mapped and studied in detail (Warren and Cummings, 1936; Dolmage and Brown, 1945; Lee, 1951), but less attention was devoted to either the regional geology or synthesising and comparing the various gold-bearing deposits in the district.

TABLE 2-10-1
PRODUCTION DATA, HEDLEY GOLD CAMP

Mine	MINFILE No.	Ore (Tonnes)	Gold (Grams)	Silver (Grams)	Reference
1. Nickel Plate	92H/SE-038				
1904-1963		2 978 046	41 637 105	4 163 138	National Mineral Inventory (NMI) 92H/8 — AU2
2. Hedley Mascot	92H/SE-036				
1936-1949		619 022	7 248 106	1 707 021	NMI 92H/8 — AU4
3. French	92H/SE-059				
1950-1955		29 450	786 420	NA	
1957-1961		48 158	817 306	65 784	NMI 92H/8 — AU1
Jan.-Apr. 1983		1 519	11 462	58 412	George Cross Newsletter, May 19, 1983
Total		79 127	1 615 188	124 196	
4. Canty	92H/SE-064				
1939, 1941		1 483	16 480	NA	NMI 92H/8 — AU5
5. Good Hope	92H/SE-060				
1946-1948		4 241	89 516	NA	NMI 92H/8 — AU3
1982		4 990	75 270	NA	
Total		9 231	164 786	NA	
6. Maple Leaf, Pine Knot Veins (Banbury Gold Mines)	92H/SE-046				
1937		5 897	29 424	13 375	NMI 92H/8 — AU7
1982		1 179	4 124	NA	
Total		7 076	33 548	13 375	
Total Production		3 693 985	50 715 213	6 007 730	

* This project is a contribution to the Canada/British Columbia Mineral Development Agreement.

British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1986, Paper 1987-1.

Figure 2-10-1. Geology of the Hedley area.

LEGEND

QUARTZ PORPHYRY

SIMILKAMEEN INTRUSIONS

Granodiorite, granite (c.150 Ma)

HEDLEY INTRUSIONS

Diorite, Gabbro (c.180 Ma)

ROCKS OF UNCERTAIN AGE

Dacitic and andesitic tuffs (Units B and C)

UPPER TRIASSIC — WHISTLE CREEK SEQUENCE

Tuff, volcanic breccia, siltstone (Unit A)

Copperfield conglomerate — limestone boulder conglomerate

UPPER TRIASSIC — HEDLEY SEQUENCE

Siltstone, argillite, minor limestone and conglomerate

Limestone

PALEOZOIC — APEX MOUNTAIN GROUP

Argillite, chert, greenstone tuff, minor limestone

GOLD BEARING PROPERTIES

LOCATION NO.	NAME AND MINFILE NO.
1.	NICKEL PLATE AND MASCOT MINE (92H/SE-38, 36)
2.	FRENCH MINE (92H/SE-59)
3.	CANTY MINE (92H/SE-64)
4.	GOOD HOPE MINE (92H/SE-60)
5.	BANBURY GOLD MINE (92H/SE-46)
6.	PEGGY/HEDLEY AMALGAMATED (92H/SE-66)
7.	GOLD HILL (92H/SE-54)

Interest in the Hedley gold camp has recently revived due to Mascot Gold Mines Limited planned 1987 reopening of the Nickel Plate mine as an open-pit operation (Simpson and Ray, 1986). Current open-pit reserves total approximately 6.5 million tonnes of ore grading 5.1 grams gold per tonne.

DISTRICT GEOLOGY

The Hedley region lies within the Intermontane Belt of the Canadian Cordillera, and the overall geology of the district is presented in Figure 2-10-1. A highly deformed package of cherts, argillites, tuffaceous siltstones, greenstones and minor limestones, originally subdivided into the Independence, Bradshaw, Old Tom and Shoemaker Formations (Bostock, 1940a; Little, 1961) outcrops in the southeast portion of the area and east of Winters Creek (Figure 2-10-1). In more recent work, Milford (1984) grouped these formations into the Apex Mountain Group; Upper Devonian, Carboniferous and Middle to Late Triassic microfossils have been recovered from some units in the Apex Mountain Group (Milford, 1984; J.W.H. Monger, personal communication, 1985). The relationship between the group and the supracrustal rock units further west is uncertain, however the Apex Mountain Group is believed to represent a highly deformed ophiolite complex that formed above an easterly dipping subduction zone (Milford, 1984).

The area between Winters Creek and Whistle Creek (Figure 2-10-1) is largely underlain by a 1000 to 2000-metre-thick sedimentary and volcaniclastic package belonging in part to the Upper Triassic Nicola Group (Rice, 1947). This package has been subdivided by previous workers into numerous formations (*see* Rice, 1947, page 13); our preliminary work indicates that the package can be informally separated into a younger Whistle Creek sequence to the west and an older Hedley sequence to the east (Figures 2-10-1 and 2-10-2). The latter comprises a generally westerly dipping, 450 to 600-metre-thick succession of sedimentary rocks that are characterized by thin-bedded, calcareous and cherty turbiditic siltstones (Plate 2-10-1), black argillites and impure limestone beds of variable thickness. Some parts of the Hedley sequence, particularly its upper portion, contain appreciable amounts of fine-grained volcaniclastic and crystal tuff material. Numerous limestone samples collected from the sequence by J.W.H. Monger and D. Tempelman-Kluit of the Geological Survey of Canada and by the present authors yielded conodonts of Carnian to Early Norian age (M.J. Orchard, personal communication, 1985, 1986).

An east-west facies change is recognized in the Hedley sequence and is believed to reflect an original, tectonically controlled, westerly sloping basin margin. West of the Bradshaw fault (Figure 2-10-1) the sequence comprises deeper water black argillites, distal turbiditic siltstones (Plate 2-10-1) and dark impure limestone beds that seldom exceed 5 metres in thickness. East and southeast of the fault however, (Figure 2-10-1) the sedimentary rocks indicate deposition in a more proximal, shallower marine, possibly fore-reef environment. This proximal succession includes turbiditic siltstones, wackes and minor impersistent grit and chert pebble conglomerate horizons, as well as massive to conglomeratic reefal limestone beds that locally exceed 75 metres in thickness. One limestone-rich unit, the "Sunnyside limestone", is traceable discontinuously for several kilometres along strike between Hedley township and the Nickel Plate mine (Camsell, 1910; Bostock, 1930, 1940a). The siltstones and thick, massive limestone beds east of Ashnola Hill* (Figure 2-10-1) represent a southern extension of the shallow marine facies of the Hedley sequence.

The Hedley sequence passes stratigraphically upwards into the 700 to 1200-metre-thick Whistle Creek sequence (Figures 2-10-2 and 2-10-3). This forms a generally westerly dipping, west-facing succession that mainly underlies the western portion of the district although small, downfaulted outliers of the sequence are present east of Hedley township and in the vicinity of Lookout Mountain (Figure 2-10-1). It contains tuffaceous siltstones and rare argillites in its lower portion, but higher in the succession is characterized by bedded to massive ash and lapilli tuffs with minor volcanic breccia.

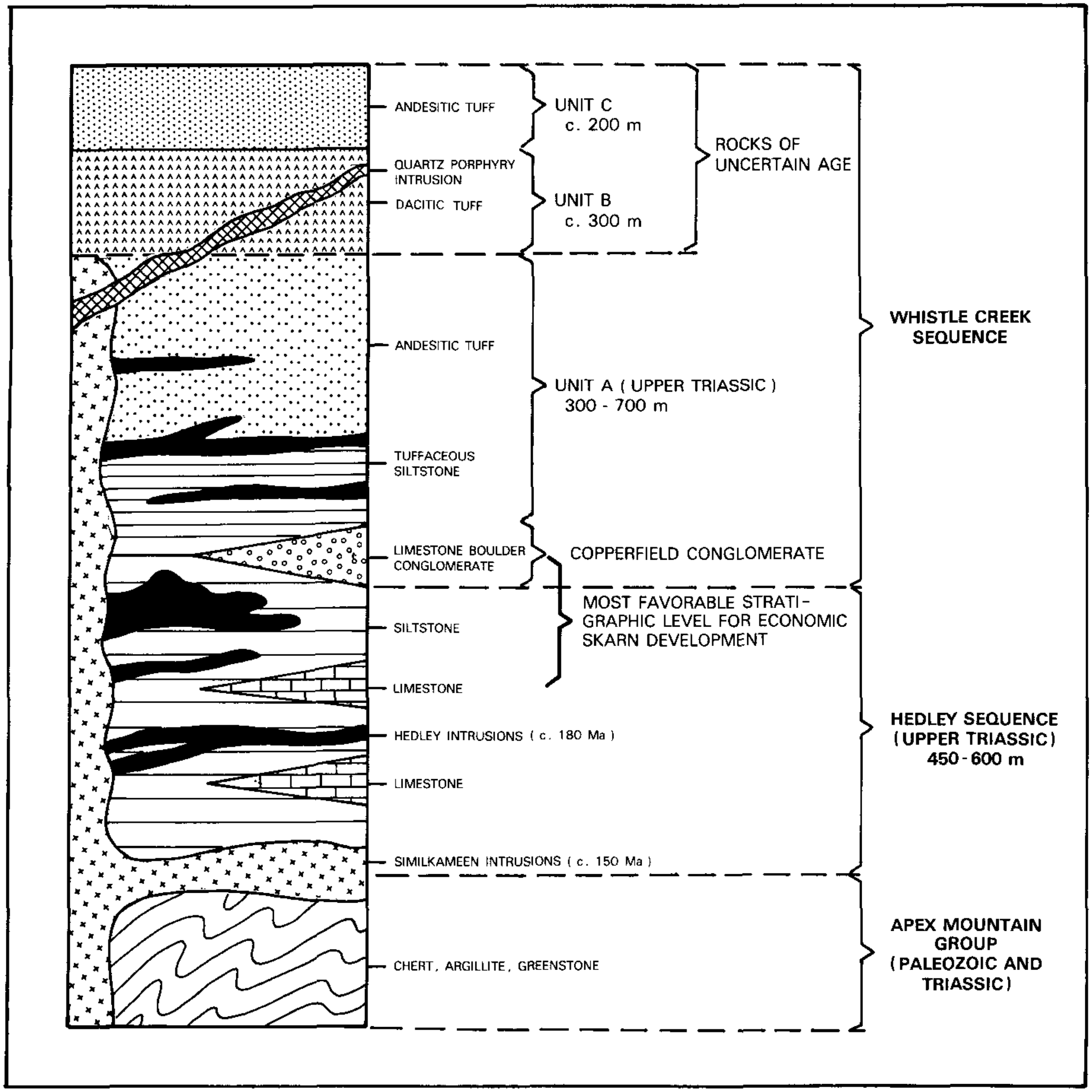

Figure 2-10-2. Schematic section illustrating the stratigraphy of the Hedley area.

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

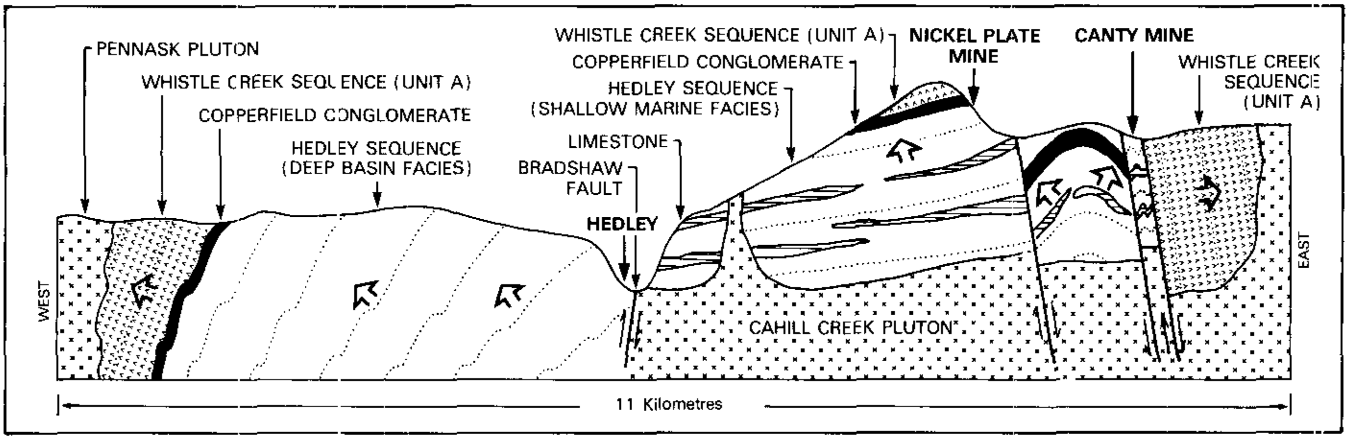

Figure 2-10-3. Schematic east-west geological section, north of the Similkameen Valley, across the Hedley area.

Plate 2-10-1. Thin-bedded turbiditic siltstones of the Hedley sequence (deeper water facies) with some graded beds; 1 kilometre west of Hedley township.

Plate 2-10-2. Limestone-boulder-bearing Copperfield conglomerate; 0.6 kilometre west of Henri Creek.

The Whistle Creek sequence is distinguished from the underlying rocks by a general lack of limestones and a predominance of volcaniclastic material. No volcanic flows have been identified in the sequence.

The Whistle Creek sequence is divisible into three stratigraphic units, the oldest (Unit A, Figure 2-10-2) is believed to be Late Triassic in age, while the precise age of the upper two younger units (Units B and C, Figure 2-10-2) is uncertain. Unit A is mainly comprised of well-bedded to massive ash tuffs of andesitic to basaltic composition. In its lower portion the unit is predominantly sedimentary in character and includes tuffaceous siltstones, interbedded with thin horizons of well-bedded to massive crystal-lithic tuff. Higher in the unit, ash tuffs with minor lapilli tuffs and volcanic breccias predominate; individual horizons are thicker and more massive, and sedimentary bedding is uncommon. Thin-section studies reveal that many ash tuffs in Unit A contain abundant euhedral, pristine crystals of plagioclase and pyroxene that show little evidence of mechanical abrasion or transportation.

The stratigraphically overlying Unit B which underlies the area northeast of Lookout Mountain and also outcrops in the vicinity of Ashnola Hill (Figure 2-10-1) has a maximum thickness of approximately 300 metres. It is characterized by massive, grey-coloured ash tuffs of probable dacitic composition. These tuffs carry well-rounded, partially resorbed, volcanogenic quartz crystals and locally contain angular lapilli of dacite, rhyolite and quartz porphyry. At one locality close to Ashnola Hill these rocks are maroon coloured and contain flattened, possibly welded pumice fragments suggesting subaerial deposition.

The youngest rocks in the Hedley sequence (Unit C, Figure 2-10-2) are confined to the southern part of the area, southwest of Ashnola Hill, and have an estimated thickness of 200 metres. They comprise mainly fresh, massive, dark green crystal-lithic tuffs of andesitic to basaltic composition, many of which are characterized by abundant large, euhedral plagioclase crystals.

The Whistle Creek and Hedley sequences are separated by a limestone boulder conglomerate (Figure 2-10-2; Plate 2-10-2) which forms the most distinctive and important stratigraphic marker horizon in the district. This conglomerate is best developed west of Hedley where it forms a northerly trending, steeply dipping unit that is traceable discontinuously for over 15 kilometres along strike (Figure 2-10-1). Remnant outliers of the same conglomerate are also seen further east, in the Nickel Plate mine-Lookout Mountain vicinity, where it was originally called the "Copperfield breccia" (Camsell, 1910; Bostock, 1930; Billingsley and Hume, 1941). During preliminary regional mapping work (Ray *et al.*, 1986) this unit was informally called the "Henri Creek conglomerate"; due to precedence, it is now informally renamed the "Copperfield conglomerate".

The Copperfield conglomerate is best developed and exposed west and northwest of the Banbury Gold Mines property (Figure 2-10-1) where it reaches its maximum thickness of 200 metres. Elsewhere, it is often less than 10 metres thick, but is well developed south of Lookout Mountain (100 metres thick), and southeast of Ashnola Hill (70 metres thick). The conglomerate 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 (Plate 2-10-2). In some localities, rare limestone blocks and olistoliths up to 15 metres in diameter are present, usually at the stratigraphic base of the conglomerate. Limestone generally comprises more than 95 per cent of the clasts but rare clasts of argillite, siltstone, wacke, chert, crystalline quartz, and both felsic plutonic and acid to intermediate volcanic rocks are also present. The limestone clasts vary considerably in appearance, from grey to buff to pink in colour, from fine to coarse grained, and from massive to thin-bedded. Some limestone boulders contain fragments of bivalve shells and crinoid stems, and a few are composed of a limestone conglomerate comprising grey limestone clasts cemented in a calcareous matrix. Other less common boulders consist of chert pebble conglomerate with a gritty calcareous matrix.

Some of the larger, elongate, siltstone clasts are deformed and exhibit soft sediment deformation structures, suggesting that they were unlithified when incorporated into the conglomerate. The conglomerate throughout the district exhibits both normal and reverse grading; larger blocks and boulders are generally more common towards the stratigraphic base, and finer grained, moderately bedded grits and conglomerates are found towards the top of the unit. The conglomerate matrix varies from massive to thin-bedded and ranges from siliceous and gritty to calcareous or finely tuffaceous; locally it shows evidence of chaotic slumping and soft sediment disruption. Conodonts extracted from some limestone boulders give Carnian ages (J.W.H. Monger and M.J. Orchard, personal communication, 1985, 1986), while radiolarians of Permian age were extracted from one chert pebble (F. Cordey, personal communication, 1985).

The Copperfield conglomerate is interpreted to be an olistostrome. It probably resulted from the catastrophic slumping of an unstable accumulation of reef debris down a steep submarine slope, and the widespread chaotic deposition of this mass onto a sequence of unlithified, deeper water turbidites. South of Lookout Mountain (Figure 2-10-1) some of the larger limestone blocks were apparently autobrecciated during the downslope movement. They are now represented by highly angular, closely interlocking fragments, separated by a thin limy gouge matrix.

Sedimentary indicators show that the Hedley and Whistle Creek sequences generally young westward (Figure 2-10-3). Measurements of crossbeds and flame structures indicate that the Hedley sequence, and Unit A of the Whistle Creek sequence were deposited by northwesterly to southwesterly directed paleocurrents.

Three plutonic suites are recognized in the area (Figure 2-10-1). The oldest is probably Middle Jurassic in age and comprises massive, coarse-grained, hornblende-bearing diorites (Plate 2-10-3), quartz diorites and minor gabbros of the Hedley intrusions (Rice, 1947). Potassium-argon age dates from these rocks range between 170 and 190 million years (Roddick *et al.*, 1972). These rocks form 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 strike length. The suite is absent in the Apex Mountain Group, but further west is widespread throughout the Upper Triassic rocks in the Hedley district. Most of the Hedley intrusions are concentrated along a northerly trending, elongate zone that coincides with the slope-related change of sedimentary facies in the Hedley sequence. Varying degrees of sulphide-bearing skarn alteration are developed within and adjacent to many of these intrusions. 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 and French mines (Figure 2-10-1). The preliminary geochemical and mapping results of this project support their conclusions.

The second plutonic suite, the Similkameen intrusions, comprises coarse, massive, biotite ± hornblende-bearing granodiorite of presumed Late Jurassic age; most potassium-argon ages from these rocks range from 150 to 160 million years (Roddick *et al.*, 1972). These intrusions generally form large bodies such as the Pennask pluton which outcrops northwest of Hedley and a granodiorite body outcropping between Winters Creek and Hedley township (Figure 2-10-1). This body, and others of its type in the region, have been given a variety of sometimes conflicting names (Roddick *et al.*, 1972; Peto and Armstrong, 1976), but is here informally named the "Cahill Creek pluton" (Figure 2-10-1). It intrudes both the Whistle Creek and Hedley sequences, and separates these rocks from the more highly deformed ophiolitic complex of the Apex Mountain Group further to the southeast (Figure 2-10-1). North of Ashnola Hill an 8-kilometre-long, dyke-like apophysis from the pluton has been controlled by a west-southwesterly extension of the Cahill Creek fracture zone (Figure 2-10-1). Country rocks up to 1.5 kilometres from the margins of the younger Similkameen intrusions are commonly hornfelsed; some minor second generation skarn alteration is also locally present adjacent to the Cahill Creek pluton, but it is generally sulphide poor and not auriferous. Unlike the biotite hornfelsed Hedley and Whistle Creek sequences, the Apex Mountain Group rocks within the contact aureole of the Cahill Creek pluton are distinct in containing abundant cordierite.

Several extensive roof pendants of hornfelsed, highly deformed sedimentary and tuffaceous rocks are present in the Cahill Creek pluton north of Winters Creek (Figure 2-10-1). These pendants contain coarse volcanic breccias, minor chert pebble conglomerates, limestones, siltstones and a thick horizon of limestone boulder conglomerate. The boulder conglomerate is the principal host for auriferous skarn mineralization at the French mine and closely resembles the Copperfield conglomerate seen further west. However it is not known whether these two conglomerate units are

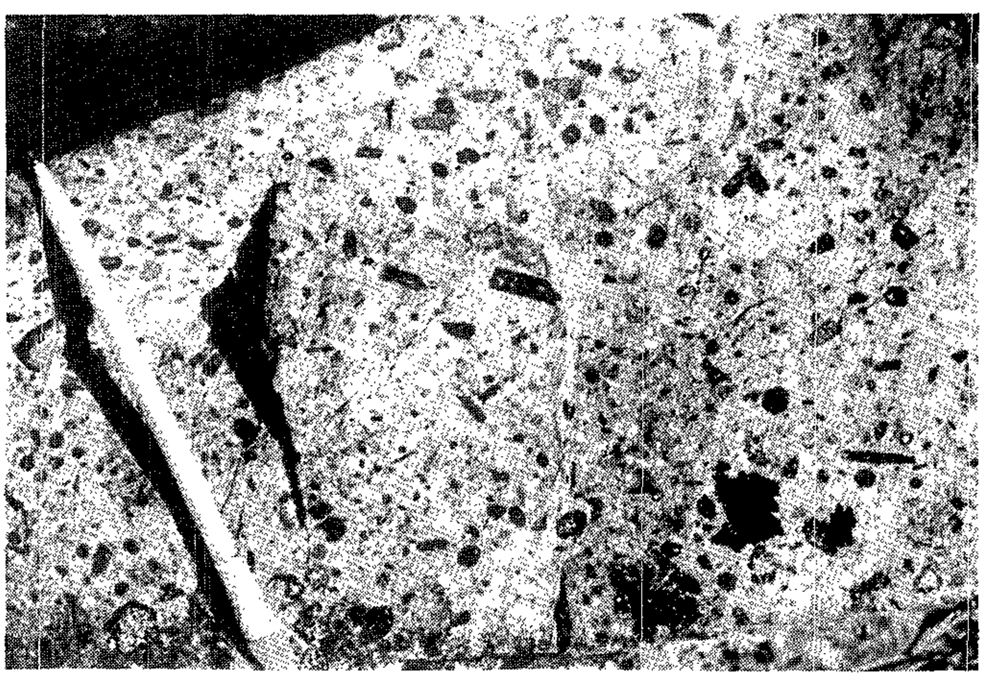

Plate 2-10-3. Dioritic Hedley intrusions with large hornblende phenocrysts. Part of a large sill that intrudes the Hedley sequence 2 kilometres north of Hedley township.

stratigraphically equivalent. The precise relationship between the deformed and hornfelsed roof pendant geology in the French mine area and the stratigraphic succession recognized further west is uncertain.

The third and youngest intrusive suite in the district is represented by a fine-grained, felsic, quartz-bearing porphyry that cuts and postdates the Cahill Creek pluton (Figure 2-10-2). These rocks are characteristically leucocratic and contain rounded, partially resorbed quartz phenocrysts up to 4 millimetres in diameter. Sills and dykes, generally less than 3 metres wide, are widespread but not abundant throughout the area. West of Ashnola Hill one 200-metre-wide, 1.3-kilometre-long dyke-like body of quartz porphyry is controlled by the west-southwest-trending Cahill Creek fracture zone (Figure 2-10-1).

The ages of Units B and C of the Whistle Creek sequence are problematic (Figure 2-10-2). They may represent a part of the Upper Triassic succession conformably overlying the Unit A rocks. However, some distinctive features suggest they could be younger and possibly equivalent in age to the Cretaceous Kingsvale or Spences Bridge Group, as first suggested by J.W.H. Monger (personal communication, 1985). These features include:

(1) The generally very fresh appearance of Units B and C,
(2) The unusual quartz-bearing and dacitic composition of Unit B, compared to the characteristic andesitic-basaltic composition of the Nicola Group tuffs further west (Preto, 1979),
(3) The common presence of Hedley intrusions in Unit A and their apparent absence in Units B and C, and
(4) The similarity between the resorbed quartz crystals in Unit B and those in the large, post-Mid-Jurassic quartz porphyry dyke near Ashnola Hill raises the possibility that these young intrusions were feeders for the Unit B volcaniclastic rocks. This age problem should be resolved by current uranium-lead dating.

Parts of Units B and C are weakly altered to skarn and if a Cretaceous age were proved for these rocks, it would indicate the existence of a third generation of skarning in the district. This alteration differs from other skarns and is typified by abundant epidote, minor amounts of small, bright red, euhedral garnets and no apparent gold.

GEOLOGICAL HISTORY OF THE AREA

The postulated early history of the area is illustrated in Figures 2-10-4A to 2-10-4D. The Late Triassic sedimentary Hedley sequence was deposited by westerly directed paleocurrents down a westerly inclined basin margin slope. This resulted in the sedimentary facies changes in the sequence with deeper water marine turbidites and thin limestone beds in the west, and shallow water marine reefal limestones and conglomeratic units in the east (Figure 2-10-4A). The basin margin slope was probably controlled by a northerly trending structure related to a major flexure within the underlying basement rocks, which are not exposed in the area (Figures 2-10-4A and 2-10-4B). The Hedley sequence sedimentation was succeeded by the catastrophic and widespread deposition of the Copperfield conglomerate across the area (Figure 2-10-4B). The appearance of this unit marks a profound change in the sedimentary environment and may reflect the sudden collapse of the basin due to regional plate movements related to the initiation of the Nicola arc further to the west.

Deposition of the Copperfield conglomerate was followed by thick airfalls of andesitic ash tuffs that immediately resulted in conditions totally unsuited to limestone development. This andesitic volcaniclastic episode was responsible for the deposition of Unit A of the Whistle Creek sequence (Figures 2-10-2 and 2-10-4C). Field data suggest that westerly directed paleocurrents still prevailed during the initial deposition of Unit A (Figure 2-10-4C). However, it is uncertain whether the andesitic airfall material was derived from the Nicola arc to the west, or from a volcanic source to the east. Initially, deposition of the Whistle Creek sequence was predominantly sedimentary in character; the tuffs are well bedded and interlayered with substantial amounts of turbiditic sediment. Higher up in the Unit A succession however, the volcaniclastic components dominate, leading to the deposition of thick, massive tuffs that rarely contain either bedding or sedimentary horizons. Although the basin continued to slowly subside at this time, there is no evidence of an east-to-west facies change in Unit A of the Whistle Creek sequence (Figure 2-10-4C).

Deposition of the Whistle Creek (Unit A) sequence was followed by a period of deformation accompanied initially by the emplacement of the Mid-Jurassic Hedley intrusions. These possibly resulted from melting in the basement during reactivation and deformation along the older basement flexure (Figure 2-10-4D). The melts moved upwards into the overlying Upper Triassic cover rocks and were emplaced as stocks, dykes and sills throughout the district. However most of the dioritic intrusive swarms were concentrated in the cover rocks along a northerly trending zone above the reactivated basement flexure (Figure 2-10-4D).

Following Mid-Jurassic dioritic plutonism, the sedimentary rocks were deformed into upright to asymmetric to overturned folds with northerly striking axial planes. This regional deformation terminated with the Late Jurassic emplacement of the Pennask and Cahill Creek plutons. The Cahill Creek pluton separates the highly deformed ophiolitic Apex Mountain Group to the southeast from the less deformed Upper Triassic rocks further to the west. If the potassium-argon age dates from the Hedley and Similkameen intrusions represent intrusive ages, the Apex Mountain Group and Upper Triassic rocks in the Hedley district were probably juxtaposed after the emplacement of the Hedley diorites and before the intrusion of the Cahill Creek pluton. It is possible that the Cahill Creek pluton was intruded along the suture zone that originally separated these two contrasting crustal units.

MINERALOGICAL ZONING ASSOCIATED WITH SKARN ALTERATION IN THE HEDLEY DISTRICT

A consistent concentric zoning of gangue mineralogy is noted at many skarn-altered outcrops throughout the district (Figure 2-10-5); it resembles some of the classical skarn-related mineral zoning patterns described at other contact metasomatic deposits in the Canadian Cordillera (Dick, 1980; Dick and Hodgson, 1982). To date these zones have only been recognized on the outcrop scale, but preliminary field evidence suggests that similar, larger scale alteration envelopes are present around the French mine deposit (Plate 2-10-4). Although thin-section studies have identified various alteration assemblages throughout the Nickel Plate-Hedley Mascot deposit similar to the French mine, no consistent large-scale mineralogical zonation has yet been identified at the property. This probably reflects the immense size of the hydrothermal system responsible for the Nickel Plate-Hedley Mascot deposit which resulted in complex temporal and spatial overprinting of the alteration assemblages.

Exoskarn alteration in the district is best developed in the well-bedded, weakly tuffaceous and limy siltstones in the upper part of the Hedley sequence; on an outcrop scale, the more intense exoskarn alteration often selectively follows the narrow, impure calcareous beds. Ideally, passage from the inner, intensely altered and carbonate-rich exoskarn core to the outer, unaltered country rock is marked by up to five concentric zones of alteration (Figure 2-10-5). These zones vary from a few millimetres to tens of metres in thickness, but in areas of weak alteration the inner zones may be absent, and only one or two of the outer alteration zones developed.

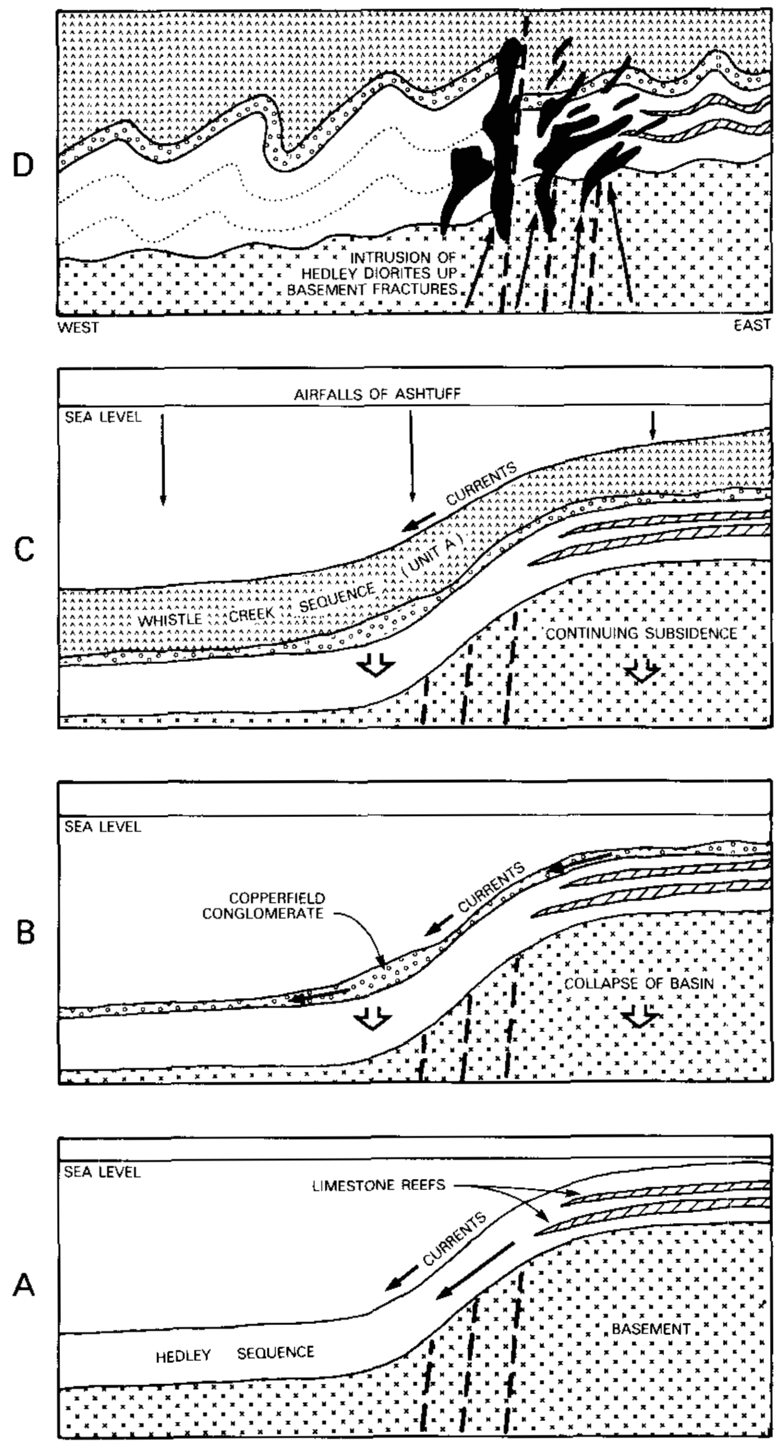

Figure 2-10-4. Postulated geological history of the Hedley area.

A — Upper Triassic (Carnian-Norian): Deposition of the Hedley sequence down a westerly inclined, basement-controlled basin margin. Shallow marine facies in the east, deeper water facies in the west.

B — Upper Triassic: Earth movements due to collapse of basin leads to the formation of the Copperfield conglomerate as a widespread gravity slide deposit.

C — Upper Triassic: Airfalls of andesitic ash tuffs result in the deposition of Unit A of the Whistle Creek sequence.

D — Mid-Jurassic: Reactivation of the basement flexure is accompanied by melting in the basement. These melts move upwards into the deforming cover rocks, resulting in the dioritic Hedley intrusions.

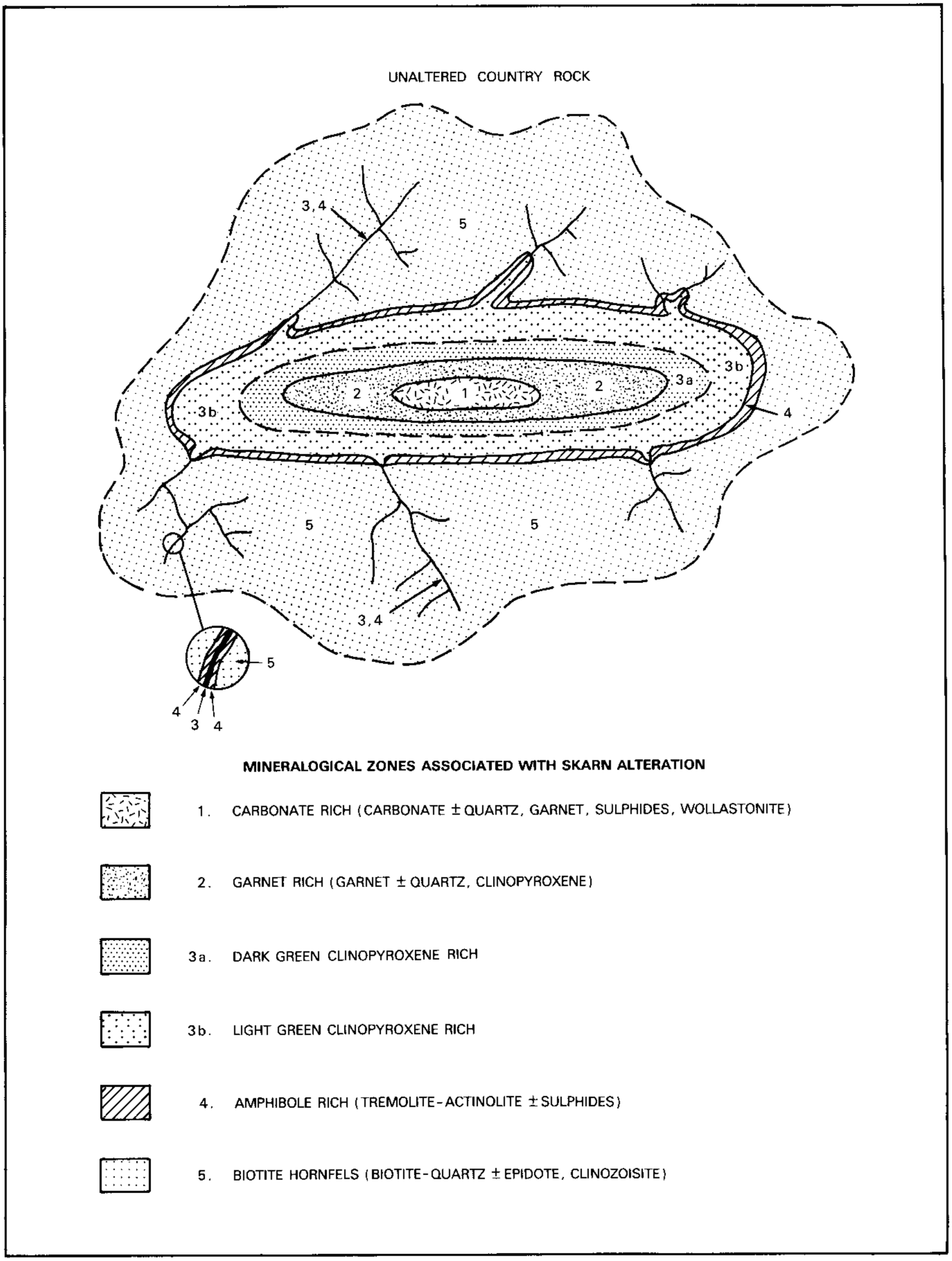

Figure 2-10-5. Mineralogical zoning associated with skarn alteration in the Hedley gold camp.

Plate 2-10-4. Samples illustrating the various mineralogical zones associated with the skarn alteration at the French mine (*see* Figure 2-10-5).

A (Zone 5) — dark, massive biotite hornfels.

B (Zone 5) — biotite hornfels cut by thin veinlets of green clinopyroxene and minor amphibole.

C (Zone 3) — massive, light to dark green clinopyroxene with minor amphibole.

D (Zone 2) — massive, dark brown coarse-grained garnetite with minor clinopyroxene.

E (Zone 1) — "Pinto Formation" — intensely skarn-altered limestone conglomerate comprising white, coarsely crystalline marble clasts within a dark brown garnetite matrix.

The innermost core (Zone 1, Figure 2-10-5) generally lies adjacent to a carbonate-rich bed; it comprises coarse crystalline carbonate intergrown with minor amounts of coarse brown garnet, quartz and some sulphides and may also contain wollastonite and some rare axinite. Zone 2 is characteristically pinkish brown in colour and garnet rich (Plate 2-10-4). It contains both massive garnetite and isolated clusters of euhedral, coarse brown garnet intergrown with lesser amounts of clinopyroxene, quartz and sporadic sulphides. Rare scapolite may also be present. In thin section the euhedral garnets (possibly andradite) display sector twinning, some growth zonation and are distinctly birefringent (low order grey coloured) under crossed polars.

Zone 3 is green coloured and clinopyroxene rich (Plate 2-10-4). It contains abundant fine to coarse-grained clinopyroxene crystals intergrown with variable amounts of quartz. Scattered garnet may be present, but in thin section garnets are seen to be partially altered to clinozoisite while some pyroxenes are replacing earlier amphibole crystals. In some outcrops, this zone is separable into an inner dark green, probably iron-rich diopsidic subzone and an outer lighter green, probably iron-poor diopsidic subzone (Subzones 3A and 3B respectively, Figure 2-10-5).

Zone 4 is generally no more than a few centimetres thick, and may even be absent (Figure 2-10-5). It is typically dark green and characterized by abundant tremolite-actinolite, with sporadic sulphides. In thin section the amphibole is seen to locally replace and pseudomorph earlier biotite.

The outermost alteration zone (Zone 5, Figure 2-10-5) is variable in thickness and may have an irregular, diffuse contact with the unaltered country rock. This biotite-hornfels zone is characteristically dark brown coloured, siliceous, massive and fine grained (Plate 2-10-4). In thin section it is seen to comprise an intimate intergrowth of very small, decussate biotite and quartz crystals with minor epidote, clinozoisite and sulphides. The outermost biotite hornfels zone is commonly cut by a network of thin, light green-coloured veinlets of diopside and minor amphibole that represent Zones 3 and 4-type alteration (Figure 2-10-5). These pyroxene-rich veinlets can be irregular, but in many outcrops they show a preferential orientation following pre-existing microfractures (Plate 2-10-4). In areas of poor exposure this distinctive diopsidic veining is a useful indicator of nearby skarn alteration and possible mineralization, and consequently its presence could indicate areas worthwhile for prospecting.

DESCRIPTIONS OF SOME GOLD PROPERTIES

The geology, mineralization and alteration at the **Nickel Plate and Hedley Mascot mines** have been documented by Camsell (1910), Warren and Cummings (1936), Billingsley and Hume (1941), Dolmage and Brown (1945), Lee (1951) and more recently by Simpson and Ray (1986). The skarn-related mineralization at the property is stratabound and has selectively followed several favourable sedimentary horizons within a well-bedded succession of calcareous and tuffaceous siltstones and limestones in the upper part of the Hedley sequence (Figure 2-10-2). This gently dipping succession was intruded and hornfelsed by swarms of flat-lying diorite sills and some vertical dykes; both the intrusions and adjacent sediments were subsequently overprinted by skarn alteration. The gold-bearing sulphide horizons tend to be found near the outer margins of the exoskarn, close to the contact between skarn-altered thin-bedded silty or tuffaceous sediments and altered carbonates and marbles. Most mineralized zones occur as semi-conformable, lenticular bodies that are structurally controlled along either fold axes, fractures developed parallel to sill margins or at the intersection of diorite sills and dykes (Billingsley and Hume, 1941). On a smaller scale there is a lithological control to the mineralization which is often preferentially concentrated along certain favourable skarn-altered sedimentary beds. In some parts of the deposit irregular pods of gold-bearing massive sulphide ore are also developed; these contain abundant pyrite, pyrrhotite, arsenopyrite and chalcopyrite. Gold in the deposit occurs in native form as minute grains associated with arsenopyrite, gersdorffite and hedleyite (Bi_7Te_3), and as electrum associated with late-stage intergrowths of chalcopyrite, pyrrhotite, magnetite and sphalerite (Table 2-10-2).

The geology of the **Canty mine** area is not well known, partly due to very poor exposure. Rice (1947) briefly describes gold-arsenopyrite-rich mineralization in a faulted and folded zone of skarn-altered sedimentary rocks similar to those at the Nickel Plate mine. Rice (1947) notes the presence of a 120 to 130-metre-wide "granitic" dyke; recent examination of drill core abandoned on the property indicates that skarn-altered Hedley diorite intrusions are also present. This mapping project showed that the area surrounding the Canty mine is underlain mostly by andesitic ash and lapilli tuffs belonging to the lower portion of the Whistle Creek sequence (Unit A); locally these rocks are skarn-altered. The mine workings lie adjacent to the major, 20-kilometre-long, Cahill Creek fracture zone (Figure 2-10-1). This curvilinear fracture dips steeply southeast and underwent several episodes of movement; the earliest episode predates and partially controlled the intrusion of the Cahill Creek pluton (Figure 2-10-1). Fault movement resulted in downthrow to the south and southeast and a 4-kilometre left lateral displacement of the Copperfield conglomerate north of Ashnola Hill (Figure 2-10-1). In the Canty mine area, the Whistle Creek sequence tuffaceous rocks east of the Cahill Creek fracture zone are structurally overturned; they dip vertically to steeply west and young eastward. By contrast, the thin unit of tuffaceous rocks in the upthrown block immediately west of the fracture is structurally upright, gently dipping and are thought to overlie Hedley sequence sediments (Figure 2-10-3). It is believed that the Canty mine mineralization is hosted by an upthrown, fault-bounded slice of Hedley sequence sediments within the Cahill Creek fracture zone. Exploration in the vicinity should therefore be concentrated along extensions of this zone, and on drilling the favourable Hedley sequence sediments that lie at shallow depth west of the fracture (Figure 2-10-3).

The **French (Oregon) mine** area (Figure 2-10-1) is underlain by faulted and folded andesitic ash and lapilli tuffs, conglomerates and some limestones which are intruded by dioritic rocks of the Hedley intrusions; these all form part of an intensely hornfelsed roof pendant within the Cahill Creek pluton. The auriferous orebodies contain arsenopyrite, bornite and chalcopyrite (Table 2-10-2), and are mainly hosted by skarn-altered limy sediments and a distinctive conglomerate known locally as the "Pinto Formation" (Plate 2-10-4). This coarse conglomerate resembles the Copperfield conglomerate but contains more chert and siltstone clasts. The skarn mineralogy at the mine includes clinopyroxene, garnet, axinite and wollastonite (Table 2-10-2). In areas of more intense alteration the conglomerate consists of angular to rounded clasts of coarse white marble, set in a brown garnetite matrix (Plate 2-10-4).

The **Peggy (Hedley Amalgamated)** property lies close to the intrusive contact between a major dioritic Hedley intrusion, the Stemwinder pluton, and steeply dipping calcareous siltstones and thin limy beds of the Hedley sequence. The sediments are intruded by several altered diorite sills. The skarn-related mineralization appears to be both lithologically and structurally controlled and has been affected by either syn or post-mineralization faulting that resulted in the growth of botryoidal pyrite and pyrrhotite. Sporadically high gold values are associated with massive pyrite-arsenopyrite, containing traces of sphalerite and chalcopyrite (Table 2-10-2).

Banbury Gold Mines Ltd. (Figure 2-10-1) is currently working ground that includes the former Maple Leaf and Pine Knot properties. Geological data gathered during this mapping project have been supplemented considerably by informative discussions with M.R. Sanford of Banbury Gold Mines Ltd. The northerly striking, steeply dipping sedimentary and tuffaceous rocks on the property are intruded by two elongate, easterly trending diorite stocks belonging to the Hedley intrusions; they extend over a strike length of 1.3 kilometres and exceed 300 metres in width. The stocks intrude the Upper Triassic succession, crosscutting calcareous siltstones, argillites and thin limestones of the Hedley sequence in the east, a

TABLE 2-10-2
MINERALOGY OF THE GOLD DEPOSITS, HEDLEY GOLD CAMP

Skarn-related Mineralization (S-type)

Nickel Plate-Hedley Mascot mines — Electrum, arsenopyrite, pyrite, pyrrhotite, sphalerite, chalcopyrite, marcasite, galena, molybdenite, magnetite, titanite, bismuth tellurides (hedleyite, tetradymite), cobaltite, erythrite, platinum (as the arsenide sperrylite collected off the stamp mills), clinopyroxene, garnet, calcite, axinite, wollastonite, scapolite, apatite, clinozoisite, epidote, biotite, tremolite-actinolite and quartz.

French mine — Arsenopyrite, pyrite, chalcopyrite, bornite, pyrrhotite, clinopyroxene, garnet, calcite, axinite, wollastonite, clinozoisite, epidote, biotite, tremolite-actinolite and quartz. Cobalt bloom seen on weathered outcrops, and anomalous tungsten values reported.

Canty mine — Arsenopyrite, pyrite, chalcopyrite, pyrrhotite, clinopyroxene, calcite, garnet, epidote and quartz.

Good Hope mine — Arsenopyrite, pyrite, chalcopyrite, pyrrhotite, native bismuth, molybdenite, hedleyite, clinopyroxene, garnet, calcite, wollastonite, biotite, epidote and quartz.

Peggy (Heldey Amalgamated) — Arsenopyrite, pyrrhotite, pyrite, chalcopyrite, sphalerite, clinopyroxene, calcite, garnet, epidote and quartz.

Vein-related Mineralization (V-type)

Banbury Gold mine (Maple Leaf, Pine Knot) — Arsenopyrite, pyrite, chalcopyrite, sphalerite, galena, native gold, quartz and calcite.

Gold Hill — Pyrite, arsenopyrite, sphalerite, galena, chalcopyrite, quartz and calcite.

200-metre-thick section of the Copperfield conglomerate in the centre, and andesitic tuffs (Unit A) of the Whistle Creek sequence in the west. Both stocks comprise two rock types, a leucocratic quartz diorite suite containing 3 to 6 per cent hornblende ± biotite to the north and a highly mafic diorite-gabbro suite characterized by 25 to 50 per cent hornblende in the south. The stocks have irregular intrusive contacts that interfinger with the bedded country rocks, and are surrounded by a hornfelsic aureole. Both the stocks and aureole are cut by several irregular, northerly trending fracture zones that are filled by steep and shallow-dipping quartz ± carbonate vein systems; these include the Maple Leaf and Pine Knot veins. Individual veins are reported to be up to 3 metres wide and exceed 100 metres in length; they contain mainly glassy to white to pale pink-coloured, strained quartz with lesser amounts of coarse calcite, sporadic visible gold, arsenopyrite, pyrrhotite, pyrite, sphalerite and chalcopyrite (Table 2-10-2). Locally they are sheared, vuggy and contain angular brecciated clasts of chloritized, silicified country rock. Some veins have sheared or faulted margins and locally the contacts are marked by thin halos of very fine sericite. Sheared quartz veins that crosscut the hornfelsic metamorphic aureole are locally enveloped by a 1-metre-wide zone of "Zebra rock" comprising thin parallel calcite veins between 2 and 6 millimetres thick, spaced regularly 1 to 2 centimetres apart. Locally, the leucocratic diorite contains pockets of intense skarn alteration marked by coarse garnet and clinopyroxene. The quartz veins crosscut and postdate this skarn alteration. The margins of some veins are intruded by late, narrow andesitic dykes that carry disseminated pyrite and pyrrhotite but no gold.

The **Gold Hill** mineralization (Figure 2-10-1), like that at the Banbury Gold Mines property, is hosted by a carbonate ± quartz vein that cuts andesitic ash and lapilli tuffs and some tuffaceous sediments in the lowest stratigraphic portion of the Whistle Creek sequence (Unit A, Figures 2-10-1 and 2-10-2). The tuffaceous rocks are intruded by dykes and sills of both fine-grained and coarse hornblende porphyritic diorite of the Hedley intrusive suite; these intrusions locally carry disseminated pyrite and arsenopyrite. Some tuff beds adjacent to one porphyritic diorite body are hornfelsed and sporadically overprinted with early calcite-diopside-pyrite-chalcopyrite skarn alteration. Later faulting, along both the intrusive margins and within the diorite body, controlled a 60-metre-long, northwest-trending, irregular carbonate vein that reaches 15 metres in outcrop width. On surface this vein comprises coarse, crystalline white to pale buff carbonate, together with minor quartz and some disseminated pyrite cubes. However spoil dumps from short adits driven on the vein contain abundant vuggy quartz vein material similar in appearance to the Maple Leaf and Pine Knot veins. This quartz-rich material contains massive blebs of coarse pyrite with traces of arsenopyrite, chalcopyrite, black sphalerite and galena (Table 2-10-2). Locally the carbonate vein margins are densely packed with elongate, interlocking, sharply angular brecciated fragments of hornfelsed and skarn-altered wallrock up to 15 centimetres long. These clasts are rimmed with two generations of carbonate growth, an early, brown-coloured, possibly ankeritic carbonate, and a later phase of white crystalline calcite that was apparently coeval with the injection of the main carbonate-quartz vein. The sequence of events at the Gold Hill property was apparently as follows: (1) intrusion of the diorite body and biotite hornfelsing of the country rock, (2) weak skarn alteration with some sulphides, (3) fault brecciation, (4) minor ankerite injection, and (5) injection of the carbonate ± quartz ± sulphide vein with hydrostatic brecciation.

AN OVERVIEW OF THE GOLD MINERALIZATION IN THE DISTRICT

The location of the more significant gold-bearing properties in the district is shown in Figure 2-10-1 and precious metal production from the mines is summarized in Table 2-10-1. All of the gold occurrences and deposits shown in the figure are spatially associated with dioritic bodies of the Hedley intrusions. These intrusions vary in size from the relatively narrow sills and dykes at the Nickel Plate and Hedley Mascot mines to the larger stocks at the Banbury and Peggy properties. The gold mineralization can be broadly separated into skarn-related (S) and vein-related (V) types. The S-type is the most widespread and economically important; it is characterized by the gold being intimately associated with variable quantities of sulphide-bearing garnet-pyroxene-carbonate exoskarn alteration (Table 2-10-2). S-type mineralization is found at the Nickel Plate, Hedley Mascot, Good Hope, Canty, French and Peggy properties (Table 2-10-1). The V-type mineralization is seen only at the Banbury and Gold Hill properties. It is characterized by gold and sulphides hosted in higher level, fracture-filled quartz-carbonate vein systems (Table 2-10-2). It is noteworthy however, that pre-vein skarn alteration of the country rock is seen immediately adjacent to some veins on these properties. The S and V-types of mineralization are believed to be related and essentially coeval. Their differences probably reflect contrasting depths of formation; the S-type originates from deeper level contact metasomatism, while the V-type represents shallower hydrothermal systems that were channeled along tension fractures.

The volume of S-type alteration developed in different parts of the district varies dramatically in scale from that produced by the huge, complex hydrothermal system responsible for the Nickel Plate-Hedley Mascot orebodies, down to smaller gold-bearing systems that gave rise to the narrow, discontinuous zones of alteration and mineralization at the Peggy property. Barren S-type alteration and its associated Hedley intrusions are extremely common and widespread, but economically auriferous skarns are very rare. Even at the Nickel Plate-Hedley Mascot mines, where the hydrothermal system produced a broad zone of skarn-related alteration up to 300 metres thick and several kilometres in discontinuous strike length, the auriferous horizons are volumetrically minute compared to the overall size of the alteration zone. The diorite intrusions at the S-type properties, even when extensively altered to endoskarn, seldom carry economic gold, although some contain anomalous gold values in the parts per billion range. In the more intensely skarn-altered diorites, the original hornblende phenocrysts are totally replaced by pyroxene and most of the igneous textures destroyed. However, their original intrusive nature can often be determined by the preservation of the distinctly zoned, coarse igneous plagioclase phenocrysts which were highly resistant to endoskarn alteration.

Economic gold values at all the S-type properties are almost wholly confined to the exoskarn; gold tends to be associated with sulphides (particularly arsenopyrite), and is not so common in the more sulphide-poor, pristine garnet-pyroxene-carbonate skarn. However, at present there is no totally reliable visual method of distinguishing barren skarn from ore. At the Nickel Plate property, for example, some arsenopyrite-rich zones are virtually barren, while in rare instances, the sulphide-lean zones are auriferous. Preliminary thin-section studies at the Nickel Plate and French mines suggest that gold is erratically associated with areas of retrograde alteration marked by late tremolite-actinolite growth.

There is an overall stratigraphic and lithological control to the gold mineralization in the camp. Most of the extensive skarn development and economic mineralization is hosted by the shallow marine facies sedimentary rocks of the Hedley sequence, particularly the 100 to 400-metre-thick limestone-rich sedimentary section that immediately underlies the Copperfield conglomerate (Figure 2-10-2). Skarn-altered conglomerate hosts the French mine mineralization (Plate 2-10-4), and the Nickel Plate-Hedley Mascot ore zones are hosted by calcareous and tuffaceous sediments that underlie stratigraphically the Copperfield conglomerate.

CONCLUSIONS

The Hedley district is mostly underlain by an Upper Triassic Nicola Group succession that is divisible into a younger, predominantly volcaniclastic Whistle Creek sequence and an older, predominantly sedimentary Hedley sequence. These are separated by a limestone-boulder-bearing olistostrome, the Copperfield conglomerate, which forms a distinctive stratigraphic marker horizon throughout the district. An east-west sedimentary facies change is recognized in the Hedley sequence reflecting a westerly inclined basin margin. Deeper water marine sediments with only minor, thin limestone beds were laid down by westerly directed paleocurrents in the west, while shallower water siltstones, conglomerates and thick reefal limestones were deposited in the east. The change from shallow to deep water facies rocks coincides approximately with the late, northerly trending Bradshaw fault (Figure 2-10-1), and the basin margin was probably controlled by an ancient structural flexure in the basement rocks believed to underlie the Triassic cover (Figure 2-10-4A).

Reactivation of the basement flexure during the Middle Jurassic led to the melting responsible for the dioritic Hedley intrusions. These melts moved upwards into the cover rocks and are now concentrated along a northerly trending, basement-controlled zone that marks the change from shallow to deep water facies in the Hedley sequence (Figure 2-10-4D).

Subsequently, the moderately deformed Whistle Creek and Hedley sequences were juxtaposed against the highly deformed, ophiolitic Apex Mountain Group further to the southeast. The contact between the Nicola and Apex Mountain Groups probably represents a fundamental fracture or suture zone that was later intruded and sealed by the Late Jurassic, granodioritic Cahill Creek pluton.

The lowest portion of the Whistle Creek sequence (Unit A) comprises andesitic tuffs that are believed to be stratigraphically equivalent to the Nicola Group rocks further west. However the upper portions of the sequence (Units B and C) include fresh, quartz-bearing dacitic tuffs that may belong either to the Upper Triassic Nicola Group or to the Cretaceous Kingsvale or Spences Bridge Groups. If a Cretaceous age was proved for these rocks, it would indicate the existence of a major unconformity within the Whistle Creek sequence.

The Early Jurassic Hedley intrusions are spatially associated with two contrasting, but essentially coeval types of gold mineralization. The most widespread and economically significant (S-type) is associated with deeper level contact metasomatic diopside-garnet-carbonate skarn alteration assemblages, while the V-type is poorly developed, less economically important and is associated with higher level, tension-fracture-filled quartz-carbonate vein systems. The volume of S-type skarn alteration developed throughout the district varies in scale from outcrop size up to the huge alteration zone surrounding the Nickel Plate-Hedley Mascot orebodies. Barren S-type skarn alteration and its associated Hedley intrusions are extremely widespread in the district but auriferous skarns are very rare. Economic gold values are almost wholly confined to the exoskarn, but there is no totally reliable visual method of distinguishing barren skarn from ore. A small-scale, consistent, concentric zoning of gangue mineralogy is present at many skarn-altered outcrops (Figure 2-10-5). Preliminary studies suggest that similar, larger scale mineralogical zoning patterns may surround some of the S-type gold deposits (Plate 2-10-4). If proven, this could provide an additional exploration tool for outlining S-type mineralization.

The main controls of S-type mineralization in the camp are:

(1) The presence of numerous Hedley intrusions, particularly swarms of sills and dykes which are considered more favourable for contact metasomatism than larger stocks.

(2) The presence of the limestone-rich, shallow marine facies sedimentary rocks of the Hedley sequence. There is an overall stratigraphic control to the skarn development and economic mineralization in the camp; the 100 to 400-metre-thick succession that immediately underlies the Copperfield conglomerate is the preferred host for mineralization (Figure 2-10-2).

(3) The presence of local controlling structures such as sill-dyke intersections, fractured sill margins and fold hinges, as noted by Billingsley and Hume (1941) at the Nickel Plate mine.

These controls suggest that:

(1) Outlining possible northern and southern regional extensions of the Upper Triassic basin margin and its associated Hedley intrusive swarms outside the Hedley camp could help locate other areas containing Hedley-type gold mineralization.

(2) Since most of the economic mineralization in the camp is stratigraphically and lithologically controlled within the upper 400-metre-thick section of the Hedley sequence shallow marine facies rocks, and the overlying Copperfield conglomerate, areas containing skarn alteration in this stratigraphic position warrant more detailed exploration.

Some extensive areas with these favourable features were noted during this program. They include:

(1) The area east of the Bradshaw fault, south of Lookout Mountain and north and northwest of the Nickel Plate mine (Figure 2-10-1). Widespread skarn alteration with some arsenopyrite is found over a broad area within a thick section in the upper part of the Hedley sequence. This section could represent a downfaulted, northerly extension of the Nickel Plate mine mineralized horizons.

(2) The Copperfield conglomerate and reefal limestone-bearing Hedley sequence rocks east of Ashnola Hill (Figure 2-10-1) are intruded by swarms of dioritic sills and extensively skarn altered. A broad, northerly trending zone of skarn alteration with sporadic arsenopyrite is seen over a strike length of 3 kilometres.

Finally, although the V-type mineralization has been economically disappointing in the camp (Table 2-10-1), these higher level veins probably result from the venting of silica and carbonate-rich fluids produced during deeper level skarn alteration. Consequently the V-type systems could pass downward into larger, gold-rich skarn systems.

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