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THE GEOLOGY AND MINERAL DEPOSITS OF THE TOBY-HORSETHIEF CREEK MAP AREA, NORTHERN PURCELL MOUNTAINS, SOUTHEAST BRITISH COLUMBIA (82K)

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INTRODUCTION

LOCATION AND GEOLOGICAL SETTING

This report presents the results of 10 months of fieldwork, undertaken from 1985 to 1987, in the Toby-Horsethief Creek area, of the northern Purcell Mountains, west of Invermere in southeast British Columbia (Figure 1). The Purcell Mountains constitute a major north-plunging culmination, known as the Purcell anticlinorium, a parautochthonous terrane of Helikian through Middle Devonian strata (Price, 1981). The stratigraphy of the Purcell anticlinorium consists of four epicratonic megasequences; the Helikian Belt-Purcell Supergroup; the Hadrynian Windermere Supergroup and the Lower and Upper Paleozoic sequences of the Cordilleran miogeocline. These sequences were folded and thrust into a regional north plunging anticline, above a major crustal scale ramp during the Columbian (Mid-Jurassic) to Laramide (Late Cretaceous - Paleocene) Orogeny (Price, 1981).

The northeastern flank of the Purcell anticlinorium comprises a northwest plunging antiformal stack of northeasterly vergent thrust sheets, consisting of sub-lower greenschist facies metasediments, penetratively deformed by one and commonly two fold events (Pope, 1989). Spatial distribution, thickness and facies variations of late Helikian through Middle Devonian strata indicate that sedimentation in this area was controlled by extensional fault systems related to a high standing block. This block, referred to variously as the 'Windermere Landmass' (Walker, 1926), the 'Windermere High' (Reesor, 1973; used herein) or 'Purcell Arch' (Root, 1983) is interpreted as a high standing block on the terraced passive margin of ancestral North America (Pope, 1989). The locus of this block, which was partly reactivated by Mesozoic to Tertiary thrust faulting (Root, 1983; Pope, 1989) is now present in the Toby-Horsethief Creek map area.

AIMS

This report summarizes the descriptive database arising from research into the stratigraphic and structural

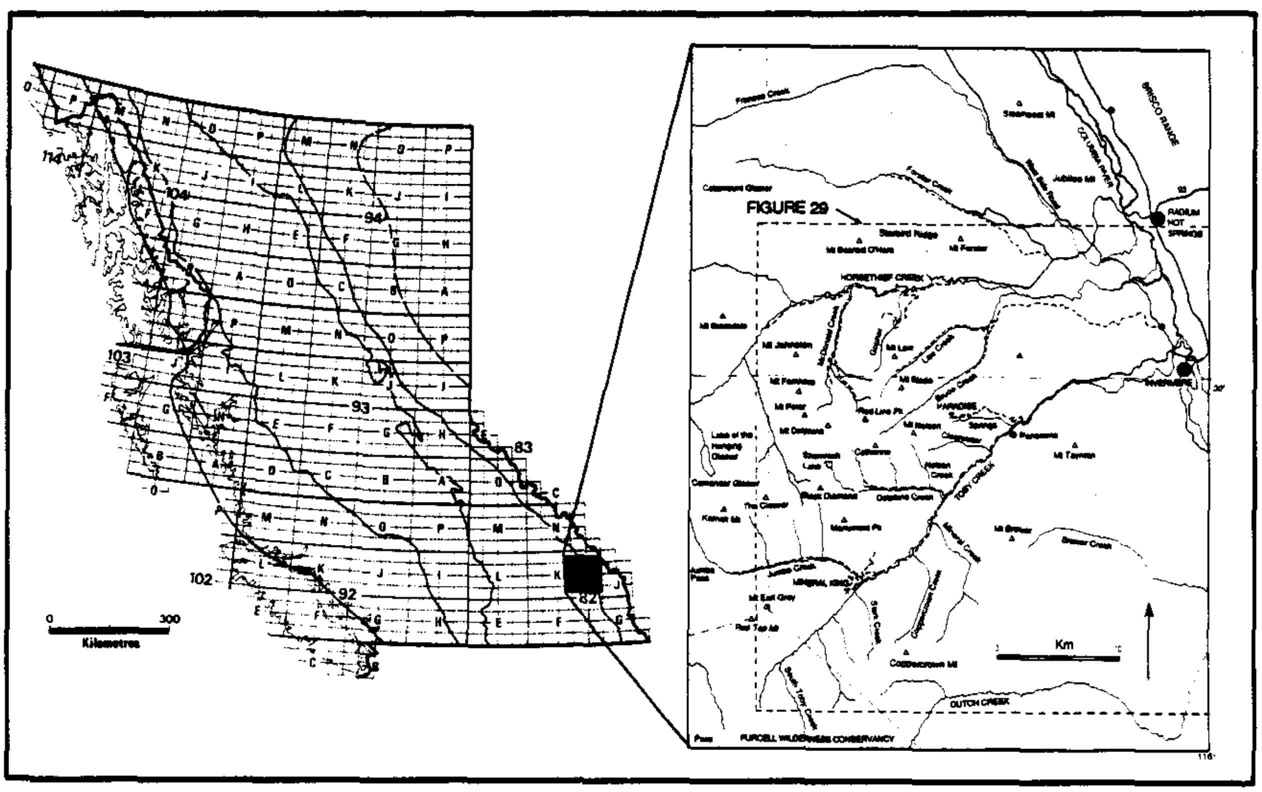

Figure 1. Location Map.

controls on metallogeny in the Toby Horsethief Creek area, with application to the northern Purcell Anticlinorium.

Particular emphasis is given to the stratigraphy of the Upper Belt Purcell Supergroup [which is problematical in the northern Purcell Mountains (Walker, 1926; Reesor, 1973)]; and to detailed descriptions of the main lead, zinc, silver, and copper occurrences in the area. The report is concluded with a brief summary and discussion of controls on mineralization.

FIELDWORK

An area of approximately 800 square kilometres was mapped at a scale of 1:15 000 from aerial photographs and a total of 4300 metres of stratigraphic section was measured.

Relief varies from approximately 900 metres to 3350 metres above sea level. Above the tree line, at about 2500 metres, exposure and subcrop is very good; however, glaciers, permanent snow fields and talus slopes conceal large areas, particularly on north facing slopes. The best exposures are on north facing slopes but these are frequently too steep for easy access and are shaded from the sun, which makes it difficult to discern distinctive colours and textures. Below the tree line exposure decreases and glacial moraine blankets the valley sides and pine forest and alder become dense. Access by forestry and old mining roads is generally good throughout the area but there is little road access above the tree line and even less south of Toby Creek.

Grid references (GR) referred to in the text correspond to the Universal Mercator Grid, Zone 11. Stratigraphic notation follows standard Geological Survey of Canada nomenclature as used by Reesor (1973) and shown on the key to Figure 29 (in pocket).

ACKNOWLEDGMENTS

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STRATIGRAPHY

INTRODUCTION

The Toby Horsethief Creek area contains exposures of the Upper Belt - Purcell Van Creek, Lower Gateway, Dutch Creek and Mount Nelson Formations; the Windermere Supergroup, Toby and Horsethief Creek Formations and, very incomplete and attenuated sequences of Lower and Upper Paleozoic strata; in a dominantly east verging stack of folds and thrusts (Figure 2). A summary of the stratigraphy (Figure 3) shows the stratigraphic variations between the major fault panels and graphically illustrates the evolution of the Windermere High through time. The detailed distribution of stratigraphy is shown on the geological map (Figure 29, in pocket). The location of stratigraphic measured sections referred to in the text are shown in Figure 2 and a key to the lithological and graphic logs is shown in Figure 4.

BELT-PURCELL SUPERGROUP

Belt-Purcell stratigraphy in the Toby-Horsethief Creek map area has an estimated total thickness of 4 300 metres, starting from an undefined level in the Van Creek Formation to the uppermost preserved level of the Mount Nelson Formation. Strata typically consist of thick, cliff-forming, buff weathering, light coloured, dominantly dolomitic lithologies with intercalated siliciclastic units. These units can be easily distinguished from the overlying, typically dark coloured, recessive Windermere Supergroup; the major exception is the dark coloured, fine grained siliciclastic-dominated Dutch Creek Formation.

VAN CREEK FORMATION - Hv

The Van Creek Formation is best exposed at the south end of Stark Creek, west of Coppercrown Mountain (Figure 1), where approximately 500 metres of it occurs in the core of a major anticline. The base of the Van Creek Formation was not identified in the map area. The most accessible exposure of the Van Creek Formation is within the bluffs on the south side of Toby Creek, adjacent to the bridge and about 1 kilometre (Figure 1) southwest of the Delphine Creek fork.

It consists of coarse to medium-grained, light-grey or green to dark-green quartzites, siltstones and silty argillites. The beds have consistent thicknesses of between 20 *to 50 centimetres with slightly undulose bases and truncated* tops, together with internal cross and planar lamination and grading. Van Creek quartzites grade upward into thinly bedded, pale green quartzites and then into thinly interbedded 2 to 20 centimetre pale green quartzites, silts and buff weathering dolomitic silts of the Lower Gateway Formation, Hg 1 member.

LOWER GATEWAY FORMATION - Hg

The Lower Gateway Formation is subdivided into two members, Hg1 and Hg2 (Figure 5).

Hg 1: The contact between the Van Creek and Lower Gateway formations is gradational and in the absence of the Nicol Creek Formation can only be roughly estimated. The lowermost units of the Lower Gateway Formation are identified as where carbonate first occurs in the succession. The thin bedded quartzites in this *transitional sequence are characterized by weathered* pyrite, which imparts a distinctive red spotted appearance.

The Hg1 member is estimated from cross sections and distribution (Figure 30) to be well in excess of 1000 metres thick. It consists of interbedded packages of quartzite, green siltstone and buff dolomitic siltstone and dolomite. Sedimentary structures such as cross lamination, grading, channelling and dewatering structures, are well preserved and compositional differences frequently enhance exposures. Siltstones in the dolomitic packages usually show an upwards gradation from dolomite free, finely cross-laminated silt and sand to dolomitic cross-laminated siltstone and cryptalgal to stromatolitic-laminated micritic dolomite (Figure 5). Bed thicknesses vary from generally 2 to 10 centimetres in the fine grained quartzite dominated lower part, to 10 to 50 centimetres in the upper dolomite dominated part of the Hg 1 member.

Hg2: The dolomite dominated upper part of the Hg1 member passes into a 90-metres thick, cream to buff weathering dolomite unit. The dolomite displays cryptalgal and stromatolitic laminations, cream chert intercalations, rare halite casts and silty and sandy cross lamination. Bed thickness varies between 50 centimetres to 2 metres, and grain size varies from micrite, which is typically blue-grey, to coarse sucrose-textured, light coloured recrystallized dolomite. This unit hosts the Mineral King lead-zinc-silver mine.

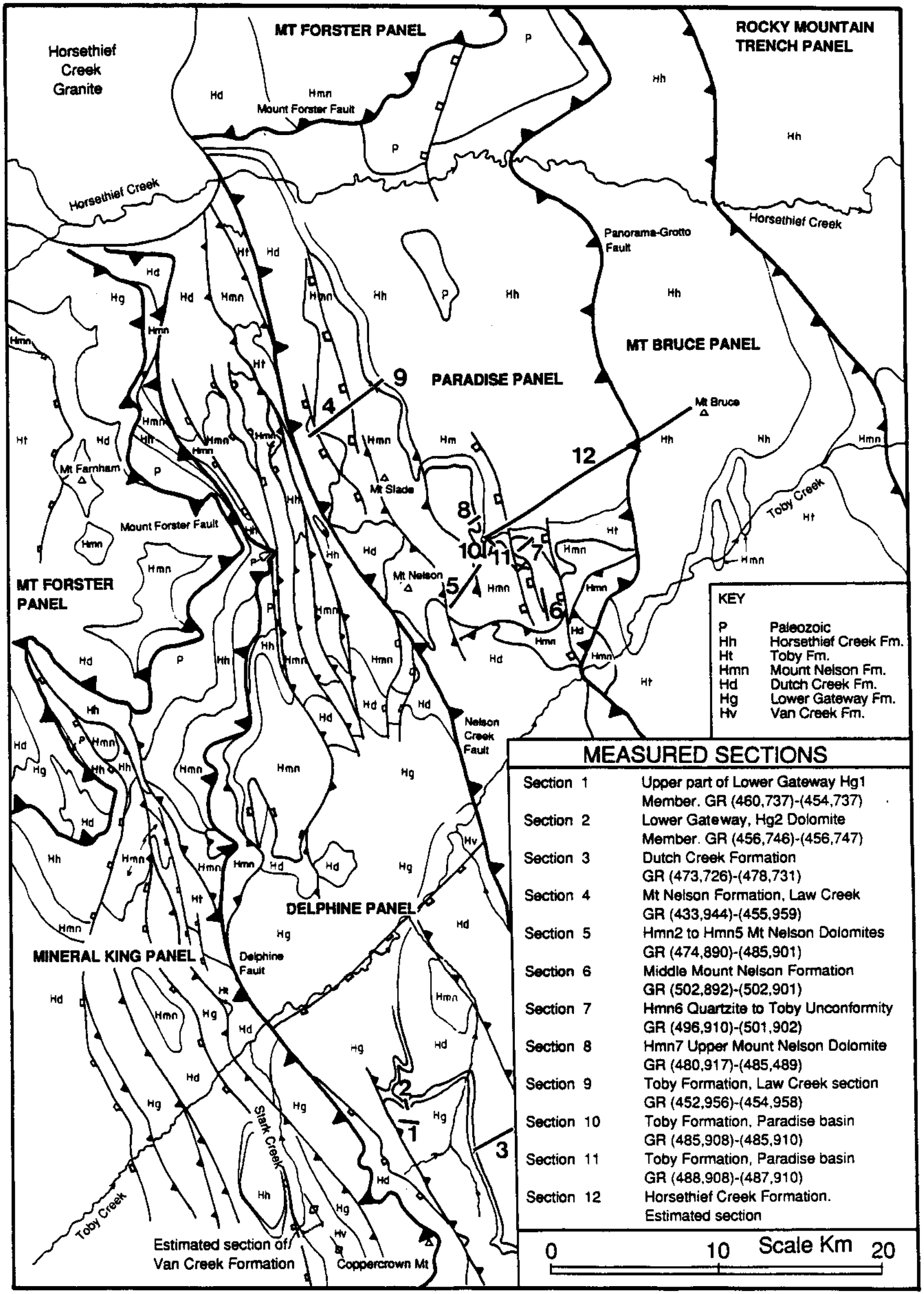


Figure 2. Summary geological map with locations of measured sections.
(Note: Sections 5, 6, 7 and 8 are not presented in this report.)

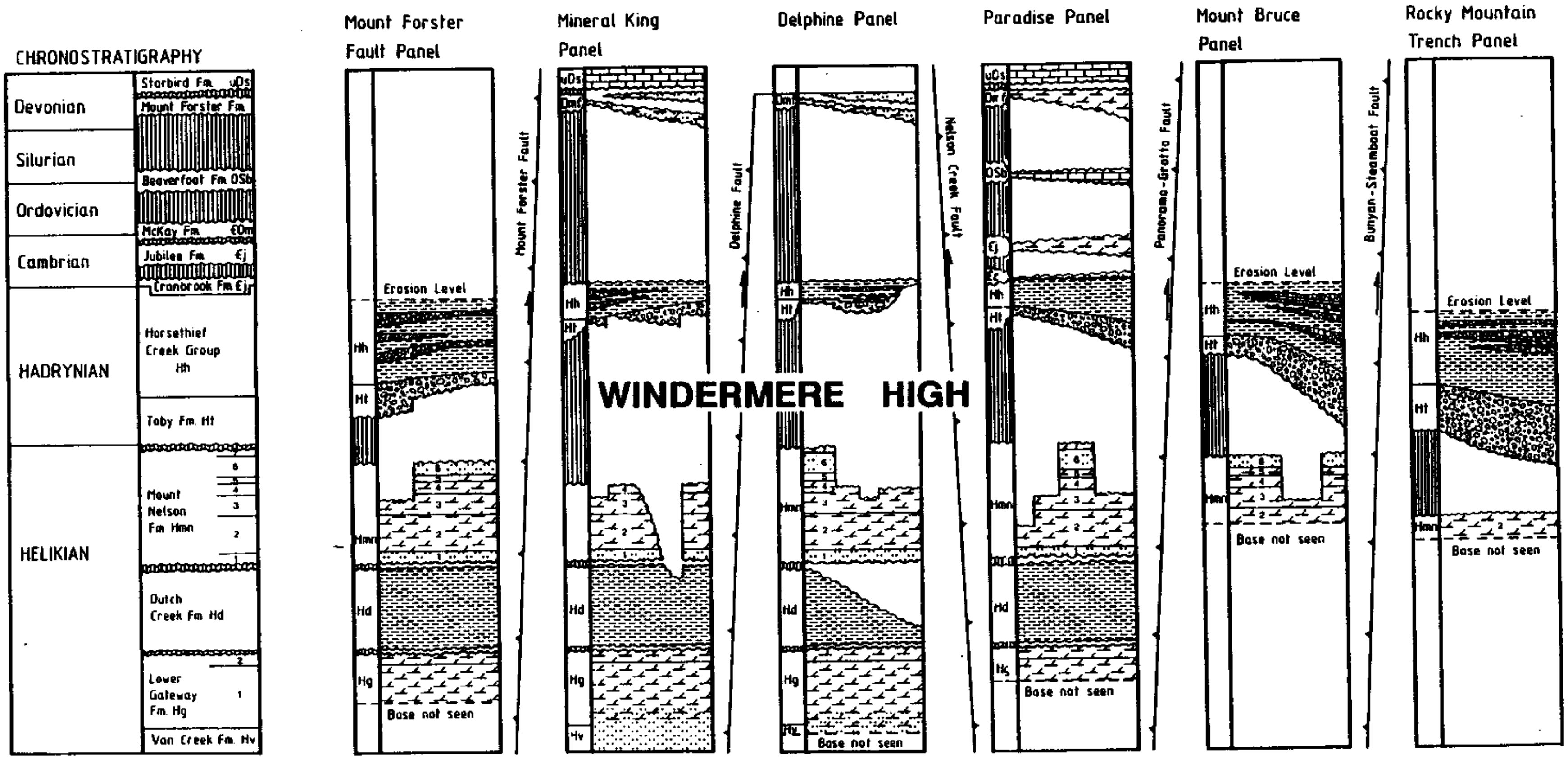


Figure 3. Summary of stratigraphy of the Toby-Horsethief Creek area.

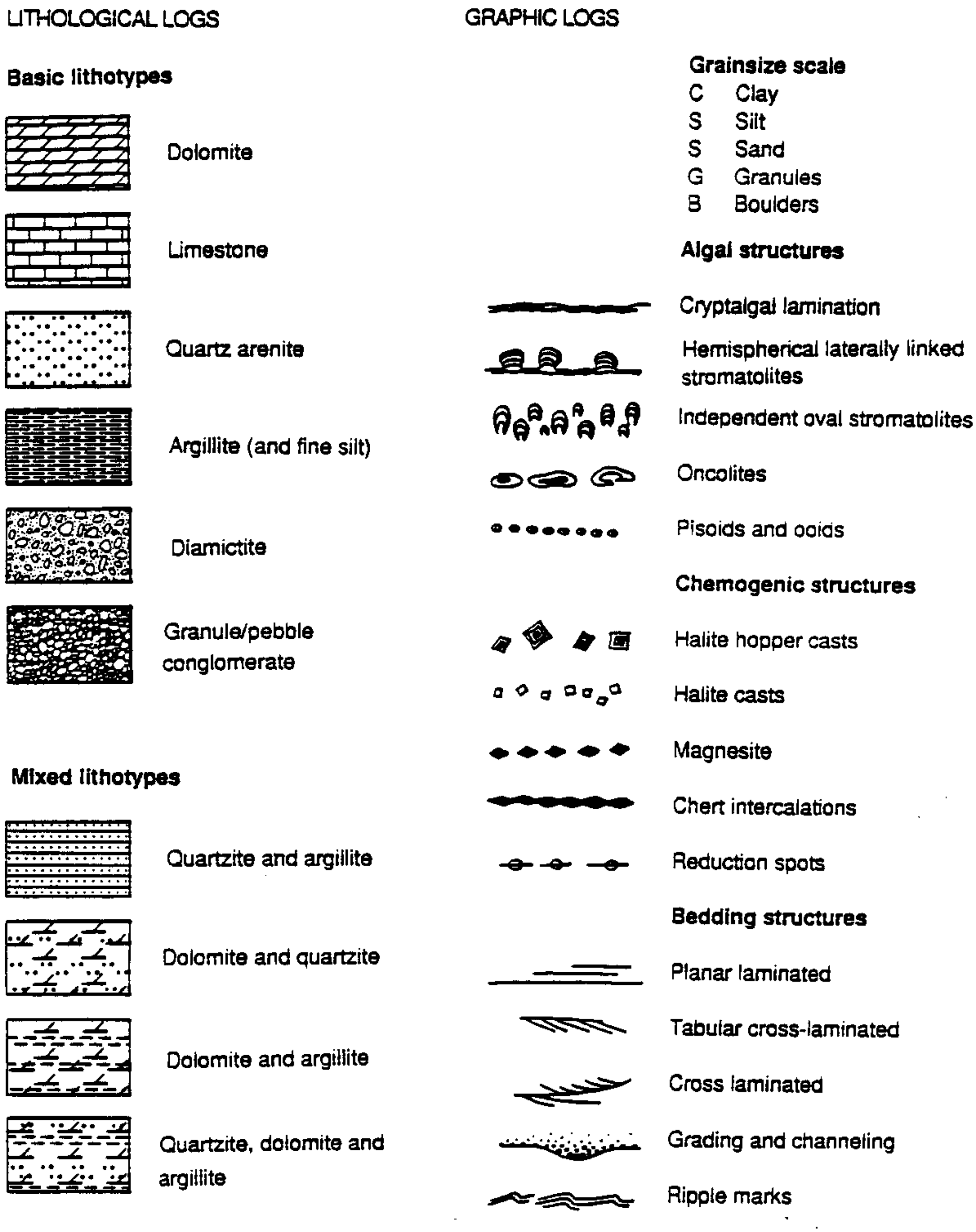


Figure 4. Key to lithological and graphic logs.

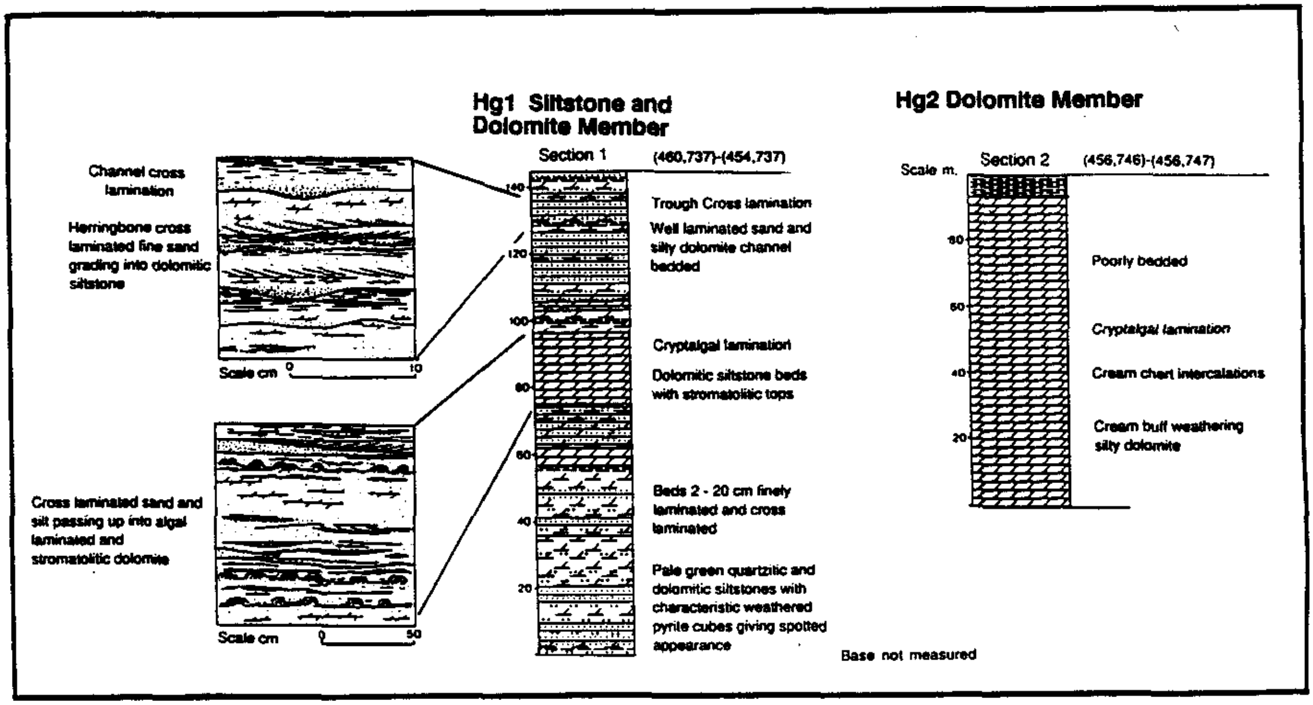


Figure 5. Sections 1 and 2 – Measured section of the Lower Gateway Formation.

DUTCH CREEK FORMATION - Hd

The boundary between the Lower Gateway Formation and the Dutch Creek Formation is clearly exposed in Coppercrown, McDonald and Farnham creeks (Figure 1). In all cases a sharp contact is observed, characterized by a narrow zone of rusty weathering. The contact is interpreted as a parallel unconformity and the rusty weathering zone marking a hiatus.

Within the Dutch Creek Formation there is not a clearly defined stratigraphy, but four basic lithofacies (A to D) have been distinguished (Figure 6). Beds are usually between 2 to 20 centimetres thick and consist of fine grained quartzite and argillite in graded couplets. Sedimentary structures include fine herringbone, ripple and channel cross-laminations. The Dutch Creek Formation has a marked lack of carbonate.

There is a great variation in thickness of the Dutch Creek Formation from an estimated 1000 metres to less than 300 metres over a lateral distance of 5 kilometres. The maximum measured thickness of the formation is 700 metres in the Coppercrown-Mineral Creek area (Figure 6). Although the observed contact with the overlying Mount Nelson Formation is always paraconformable, the contact is very sharp and represents a major change in facies, hydrodynamic energy and sedimentary processes, and is therefore interpreted as an unconformity.

MOUNT NELSON FORMATION - Hmn

The Mount Nelson Formation is the uppermost unit of the Purcell Supergroup below the Windermere unconformity. It is 1320 metres thick and consists of very distinctive thick, well-bedded sequences of white orthoquartzites, buff weathering dolomites and purple dolomites and argillites. A very precise lithostratigraphy comprising seven members, mappable at a scale of 1:50 000, has been established (Figure 7). The formation is preserved largely intact, except for the Upper Dolomite, on the north side of Law Creek (Figure 1). A measured section from Law Creek, uncorrected for fault displacements, is shown in Figure 8.

LOWER QUARTZITE - Hmn1

The lower Mount Nelson quartzite varies in thickness from 50 to 150 metres and is a useful marker horizon. It is characteristically white and consists of well sorted, fine to medium grained (0.5 to 1 millimetre) pure quartz arenites, with thin bedding (2 to 20 centimetres) and well developed planar and ripple lamination. These sedimentological features distinguish it from the upper Mount Nelson quartzite which is also white.

LOWER MAIN DOLOMITE - Hmn2

The lower main dolomite is approximately 400 metres thick and lies conformably upon the lower quartzite, with which it has a gradational contact over of 40 metres. It is easily accessible and very well exposed in the upper part of Law Creek. The dolomites are characterized by a pale-grey weathered and blue-grey fresh colour, a very consistent bedding thickness of 20 to 50 centimetres and cryptalgal to stromatolitic lamination. Individual beds usually consist of a lower cross-bedded silty (5 to 20 per cent quartz) dolomite containing soft-sediment dewatering structures, which pass upwards into

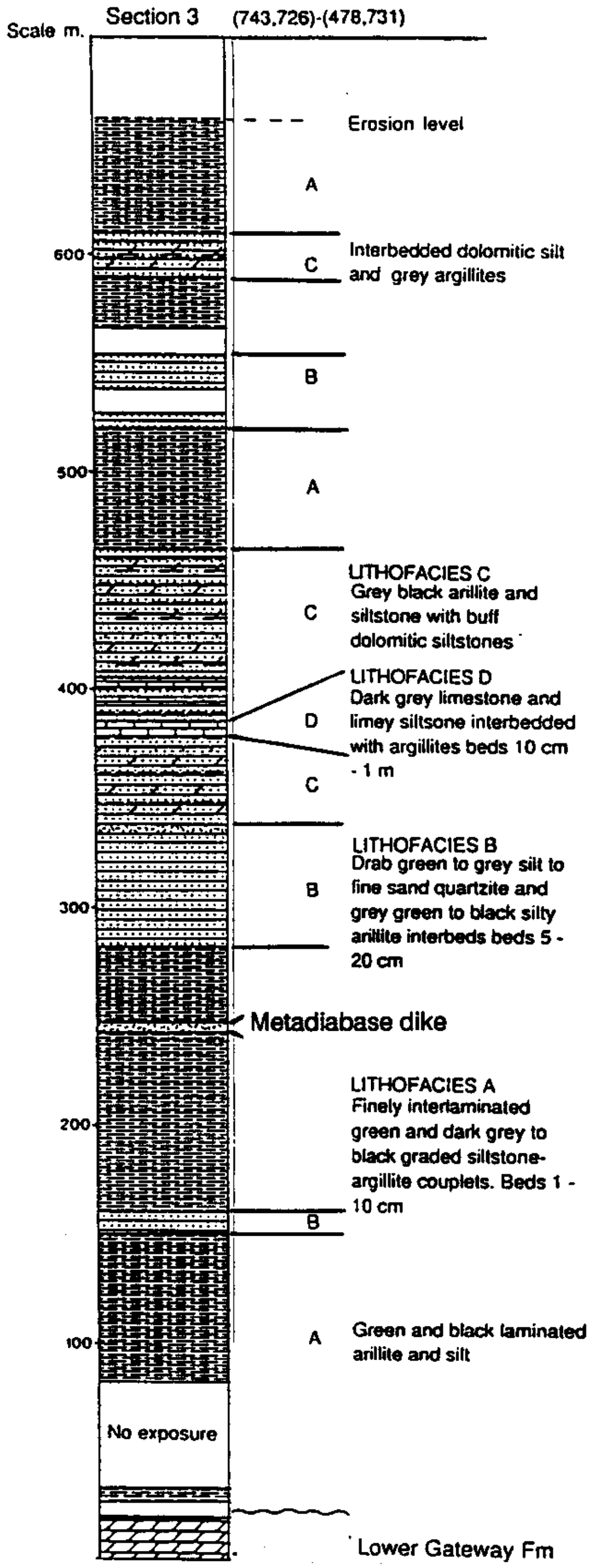


Figure 6. Section 3 - Measured section of the Dutch Creek Formation, Coppercrown Creek.

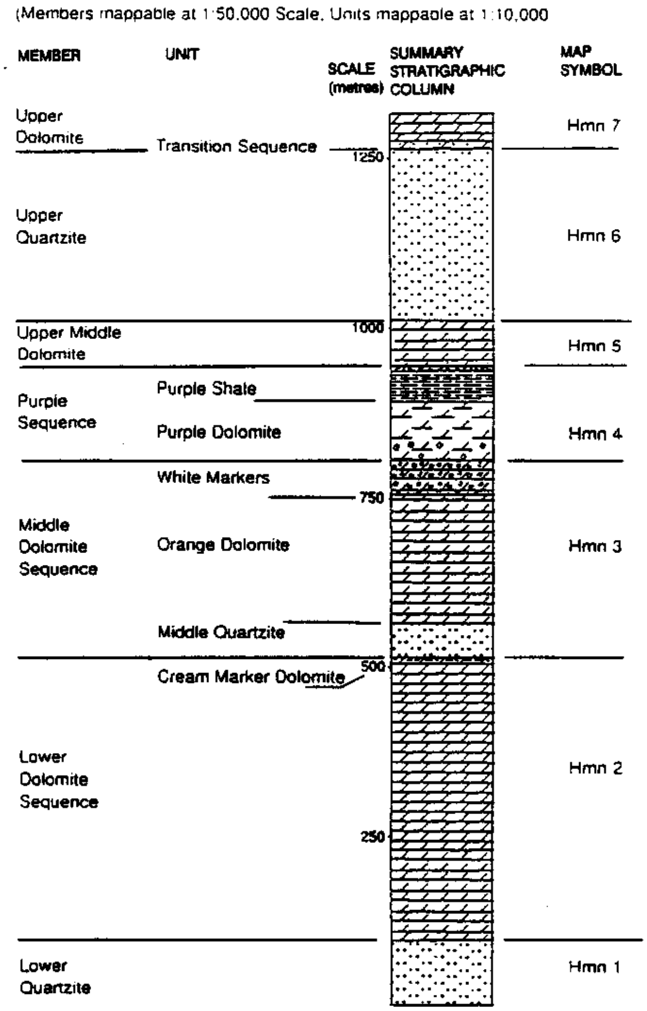


Figure 7. Stratigraphy of the Mount Nelson Formation.

cryptalgal laminated dolmicrites and hemispherical laterally-linked stromatolites. Large disseminated dolomitized halite casts, up to 3 centimetres in diameter, are common in the upper parts of beds and rare oolite laminations have been identified. Black carbonaceous argillites, 1 to 2 centimetres thick, are frequently interbedded with the dolomites.

The upper parts of the lower Main dolomite are more thickly bedded (20 to 50 centimetres), whereas the lower parts are thinner bedded and contain more terrigenous argillitic material. The sequence is capped by a distinctive cream coloured stromatolitic, crystalline cherty-dolomite unit about 20 metres thick.

MIDDLE QUARTZITE - Hmn3 a (lower part)

The middle quartzite lies with sharp contact on the lower main dolomite upper-cream marker unit. This is the 'apple green' quartzite mapped by Atkinson (1975) as the lower Mount Nelson quartzite in the Paradise map area, and is best exposed on the north side of Clearwater

Creek. The middle Mount Nelson quartzite forms the summits of Mount Nelson and Mount Catherine (Figure 1), but exposures are more easily accessible in the Law Creek section.

It is apple green in colour and consists of graded, channel cross-bedded and massive, fine to coarse-grained quartz arenites, impure sandstones and argillites. The beds commonly have undulose bases, argillite rip-up clasts, truncated tops, and are usually 10 to 20 centimetres thick but may be up to 50 centimetres. The grading, channelling and erosion surfaces in the quartzites indicate rapid deposition in the form of turbidites (Walker, 1984). Thick bedded sections display truncated A - B and A - C Bouma sequences whereas thinner bedded sections commonly display A - D and A - E sequences.

The middle quartzite grades into a section of varicoloured buff weathering dolomitic siltstones, argillites and impure sandstones at the base of the distinctive orange dolomite sequence.

ORANGE DOLOMITE - Hmn3 b (middle part)

The orange dolomite sequence, which is approximately 180 metres thick, is composed of well-bedded bright orange-buff weathering, silty and sandy crystalline dolomites with abundant stromatolites, cryptalgal lamination and chert intercalations. Solution collapse breccias, halite casts and mud cracks are common. The dolomites are typically blue-grey when fresh, although recrystallized zones within the dolomite are lighter coloured and have a sucrosic texture. Fine to medium-grained quartz-rich (5 to 20 per cent quartz) laminae define ubiquitous fine scale cross-laminations, grading and dewatering structures.

WHITE MARKERS - Hmn3 c (upper part)

Conformably above the orange dolomite is the white marker sequence, which has a maximum thickness of about 70 metres. It consists of cream, buff and silver-grey dolomites, locally developed pure-white magnesite beds up to 1 metre thick, and purple, green and buff dolomitic mudstones. Dolomites have stromatolitic laminations and cream chert intercalations which preferentially replace the algal structures. The dolomitic mudstones contain abundant halite casts. At the Kootenay Queen mine, hosted by the white marker sequence, beds up to 1 metre thick consist entirely of dolomitized halite casts.

PURPLE SEQUENCE - Hmn 4

The conformably overlying purple sequence is in gradational contact with the white marker sequence. Purple ripple-drift cross-laminated dolomitic sandstones and siltstones, with abundant halite casts, dominate the lower part of the unit which grades up into a sequence of purple argillites. The composition of the dolomitic silts is approximately 20 per cent quartz, 70 per cent fine-grained anhedral dolmicrite, and 10 per cent hematite which imparts the very distinctive purple colour. Interbedded with the silts and argillites are a number of mudchip breccias and monomict pebble conglomerates. The purple argillites in the top half of the sequence often contain green reduction spots and isolated green reduction laminae.

At the top of the sequence a conglomerate overlies and is in sharp contact with the purple shales. It consists of angular to rounded dolomite and quartzite boulders, cobbles and pebbles in a purple sandy-argillite matrix. It is interpreted as an intraformational unconformity, and attains a thickness of about 10 metres in the northern part of the Toby-Horsethief Creek area, but is less than 2 metres thick in the Paradise mine area. This is the conglomerate identified by Bennett (1985) in the area north of Horsethief Creek, with which he designates a boundary between the redefined Mount Nelson Formation below the conglomerate, and the informally named Frances Creek unit above.

UPPER MIDDLE DOLOMITE - Hmn 5

The upper middle-dolomite member is approximately 80 metres thick and is well exposed at the Paradise mine adjacent to the dam site. It is similar to the lower main dolomite and the upper dolomite but can be distinguished by the proliferation of algal allochems, in particular oncolites and oolitic, pisolitic and peloidal laminations. The allochems are typically replaced by black chert, which is very distinctive on weathered surfaces.

UPPER QUARTZITE - Hmn 6

The upper quartzite is a distinctive cliff-forming unit of white orthoquartzites in excess of 260 metres thick. This member was mapped as upper Mount Nelson quartzite by Atkinson (1975) and described as such by Reesor (1973). It is best exposed in the upper parts of Springs Creek where it forms cliffs south of the Paradise mine and forms the foundation for the mine buildings (Figures 1 and 16a). It can also be seen along Law Creek where the road negotiates a series of switchbacks adjacent to a waterfall over the quartzite.

The quartzites consist of well sorted medium to coarse-grained and generally pure arenites with a quartz overgrowth cement. Bedding varies in thickness between 20 centimetres to 1.5 metres and usually occurs as sequences of thick or thinly bedded strata. The typically lichen covered outcrop coupled with the indurated nature of the quartzites usually obscures the sedimentary structures, particularly in the thick-bedded pure quartz arenite sections. Massive bedding and poorly preserved sedimentary features distinguish the upper quartzite from the lower quartzite. Massive tabular cross beds, cross beds and rare herringbone cross lamination can occasionally be discerned from subtle colour-banding caused by differential cementation and hematite staining. Thin bedded sections

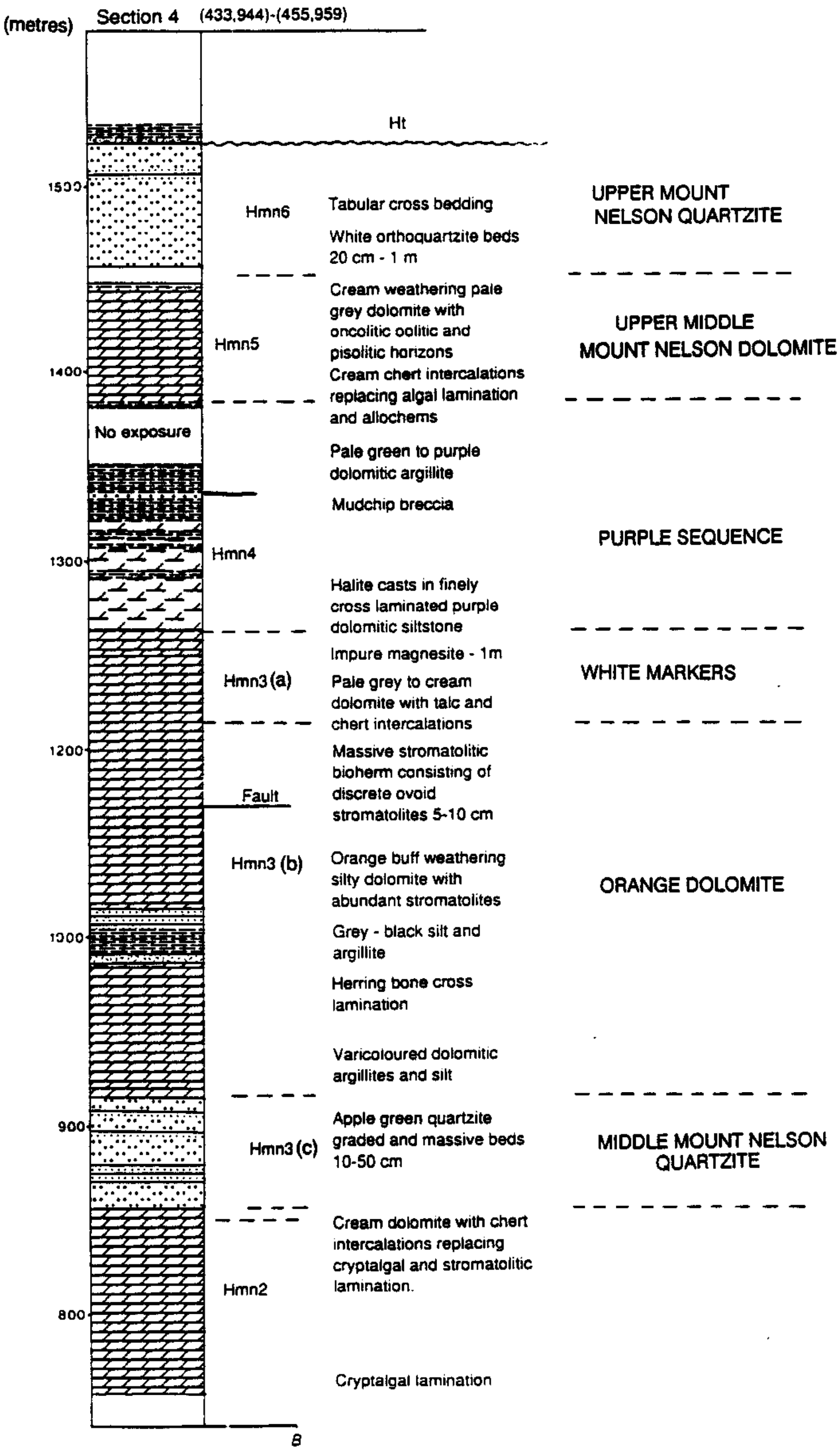
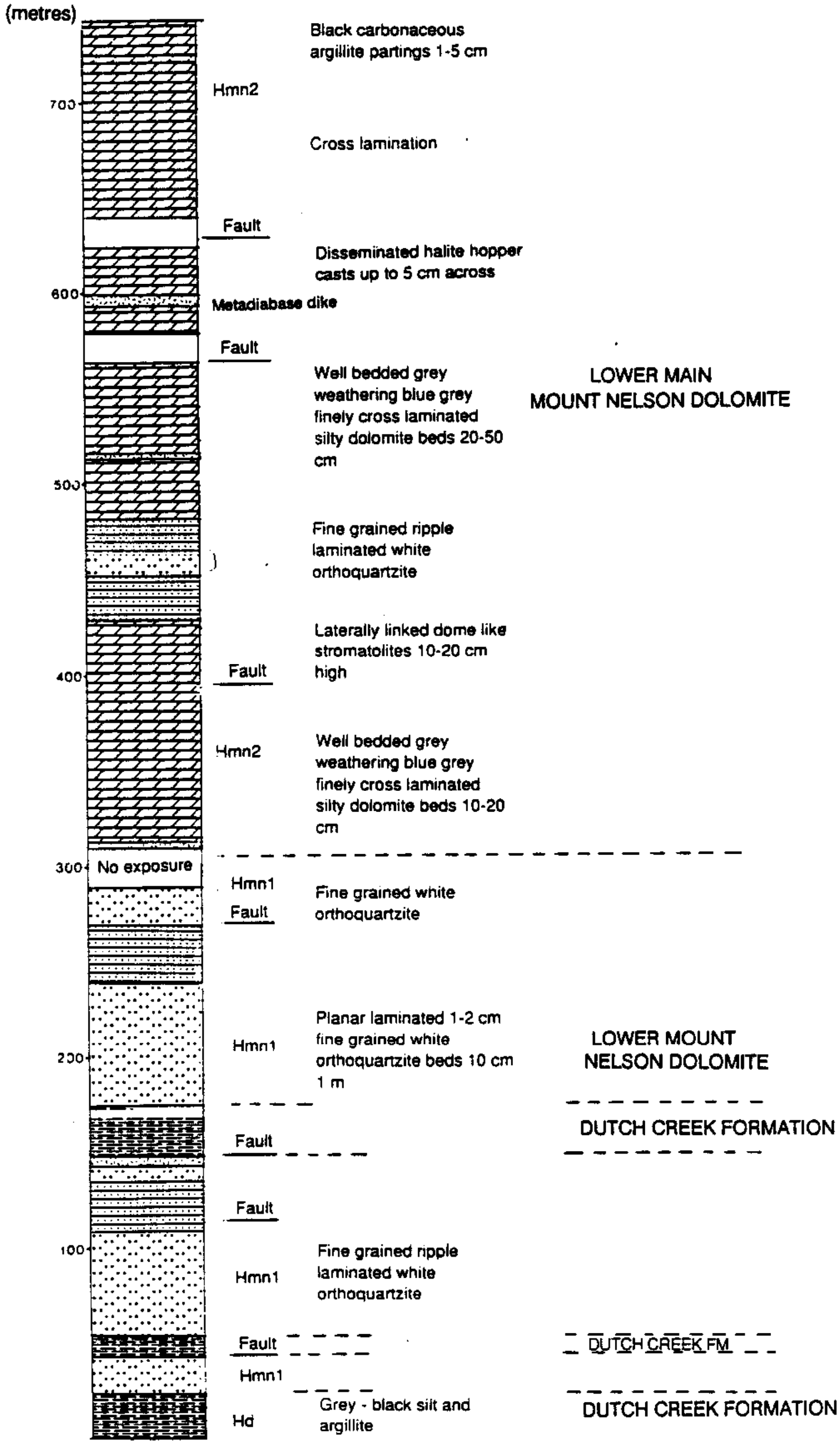


Figure 8. Section 4 – Measured section of Mount Nelson Formation, Law Creek.

Section 4 Continued.



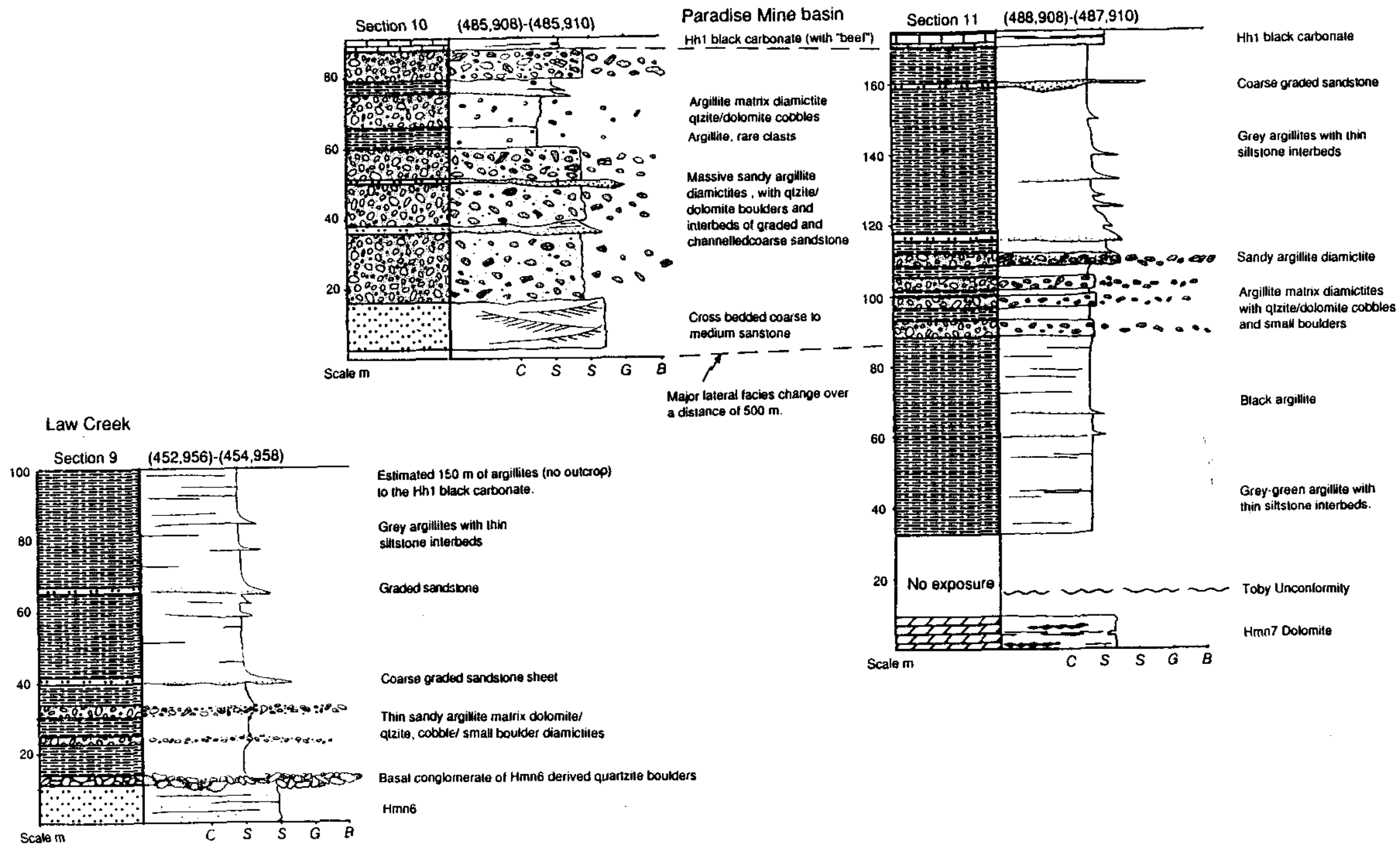


Figure 9. Sections 9, 10 and 11 – Representative sections from the Toby Formation, Paradise Mine area.

of quartzite are poorly sorted, impure and exhibit grading, channelling, unimodal and bimodal ripples.

UPPER DOLOMITE - Hmn 7

This is the uppermost unit of Belt-Purcell stratigraphy exposed in the Purcell anticlinorium below the Windermere unconformity. It is well exposed in the upper parts of Springs Creek where it hosts the Paradise Pb-Zn-Ag mine. The upper dolomite has a conformable gradational contact with the underlying quartzite, comprising a characteristic 10-metre thick interbedded purple argillite, quartzite and dolomite transitional sequence, which is exposed at the head of Springs Creek. This transitional unit is a useful marker horizon in the Paradise map area (Figure 17).

The upper dolomite is well-bedded (10 to 50 centimetres) pale to dark grey, interbedded with quartz and dolomite pebble conglomerates and dolomite-supported cross-laminated quartz sands. The dolomite is distinguished by abundant black chert layers which preferentially replace cryptalgal structures and thin carbonaceous black shale interbeds. The most characteristic feature is a very well developed fine scale (0.5 to 1 millimetre) lamination in micritic blue-grey dolomite, which is strongly contorted into microfolds and localized pockets of breccia.

WINDERMERE SUPERGROUP

The Windermere Supergroup consists of a basal conglomeratic unit, the Toby Formation, and an upper argillite and pebble conglomerate unit, the Horsethief Creek Formation, as defined by Walker (1926). It lies with very considerable and irregular unconformity on the underlying Belt-Purcell Supergroup and also shows a variation in thickness from 80 metres to greater than 3 kilometres in the Toby-Horsethief map area. This thickness variation reflects the presence of a paleo high referred to as the 'Windermere High' (Reesor, 1973; Figure 3). This supports the facies analysis based contention of Bennett and McClay (in press) that the Toby Formation is a syn-rift deposit.

The Toby Formation overlies different levels of the Belt-Purcell stratigraphy within adjacent fault panels, indicating that the faults were active during sedimentation. The 'Windermere High' is interpreted in this context as a high standing block on the terraced passive margin (Pope, 1989).

TOBY FORMATION - Ht

Four lithofacies have been identified. These lithofacies cannot be correlated across the area due to rapid lateral facies changes and they are not differentiated into mappable members at 1:50 000 scale. It would be possible to distinguish members at 1:10 000 scale. Representative measured sections from the Toby Formation are presented in Figure 9.

BOULDER BRECCIA LITHOFACIES

The breccia lithofacies is locally developed at the base of the Toby Formation and comprises monomict clast-supported boulder breccias. The breccias show very local provenance and occur as lenticular bodies, suggesting that they were deposited within irregularities in the Toby unconformity surface. The unconformity surface may be mapped locally in three dimensions and provenance can be traced to within a few tens of metres. The best example is documented in Toby Creek (GR 375, 853) where the basal boulder breccia lies in troughs in the Hmn 3 dolomite.

DIAMICTITE LITHOFACIES

The diamictite lithofacies has considerable variation. The most common diamictite type seen in the Toby-Horsethief creek area consists of rounded quartzite and subangular dolomite boulders supported in a sandy argillite matrix. This is the dominant diamictite facies exposed along the Toby Creek road (type locality of the Toby Formation from Walker, 1926), and is also well exposed on the road up to the Paradise mine in Springs Creek. A finer-grained variety comprises well-rounded quartzite pebbles and cobbles and angular dolomite pebbles and cobbles supported in an argillitic matrix. The clasts in the diamictite facies appear to be derived exclusively from the underlying Mount Nelson Formation.

SPARSE CLAST DIAMICTITE LITHOFACIES

This facies consists of graded, coarse to fine, poorly sorted arenites and argillites with rare rounded quartzite pebbles or cobbles. The arenites have poorly sorted massive basal units of quartz, lithic clasts and carbonate, overlain by graded and cross-laminated sand and silt and an upper argillite unit. Cobbles are best exposed in argillite beds where the weathering contrast is most marked.

SILTSTONE-ARGILLITE LITHOFACIES

The siltstone-argillite facies comprises the bulk of the Toby Formation and is most dominant in the upper parts of the formation. It consists of well-sorted and graded fine quartz arenites and argillites which occur in graded couplets and typically exhibit complete fine-scale Bouma sequences.

HORSETHIEF CREEK FORMATION

Typically the boundary between the Toby Formation and the Horsethief Creek Formation is gradational. A rudimentary stratigraphy of lithofacies, rather than of discrete lithological units, is recognized in the Horsethief Creek Formation. Individual units show rapid lateral thickness and facies variations, requiring detailed map-

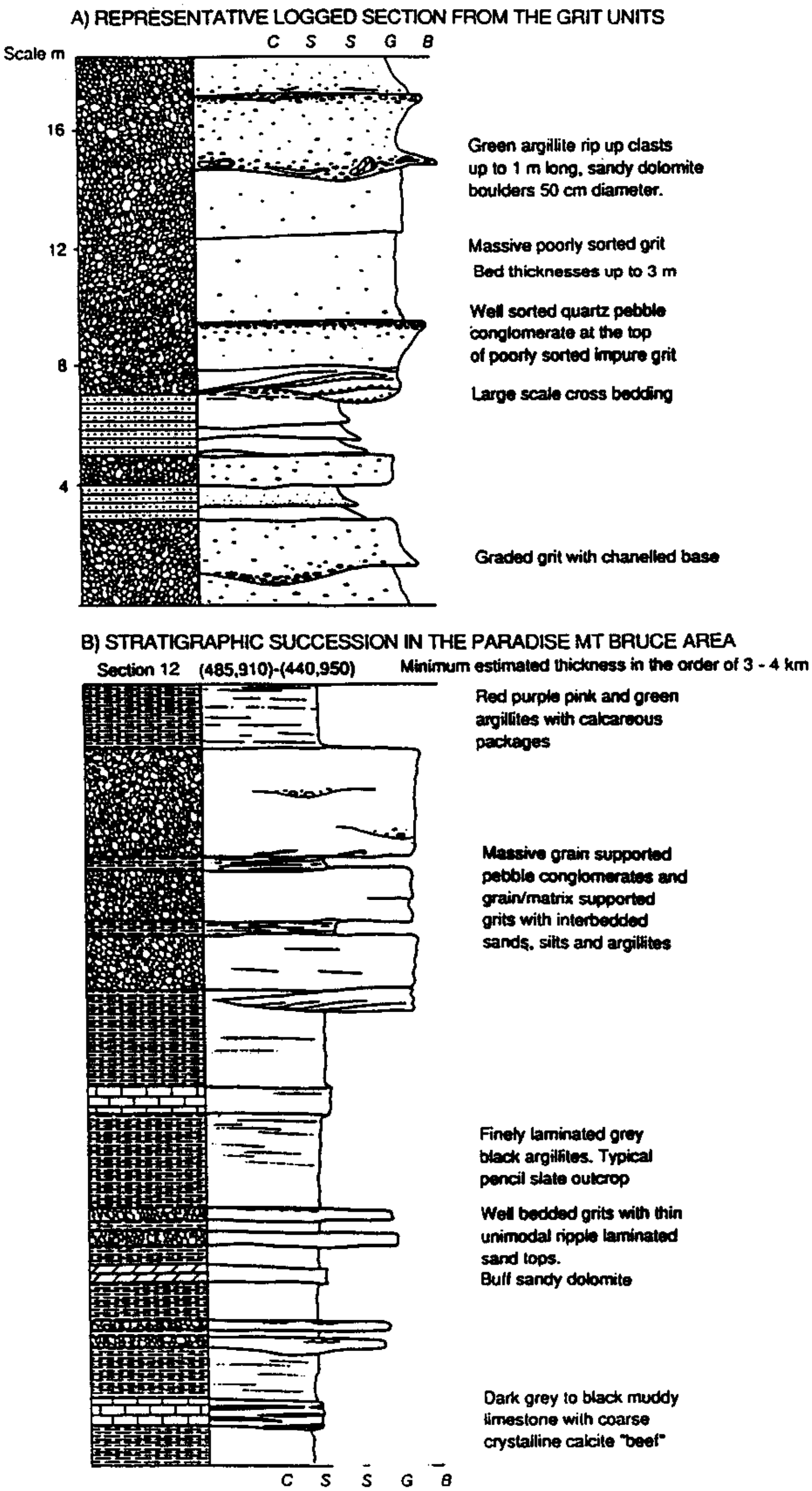


Figure 10. Stratigraphy of the Horsethief Creek Formation. (A) Representative logged section from the grit units. (B) Section 12 – Stratigraphic succession in the Paradise – Mt. Bruce area.

ping to establish direct correlations. Five lithofacies have been recognized. The siltstone-argillite lithofacies occurs throughout but is dominant in the lower half of the Formation. The other four lithofacies, which are separated by the siltstone-argillite facies, may define a rough stratigraphy, although they may occupy more than one stratigraphic position (Figure 10).

BLACK CARBONATE - Hh 1

This is an easily traced marker used to define the base of the Horsethief Creek Formation in the Toby Horsethief Creek area. It is best exposed on a small unnamed peak northeast of Watch Peak (GR 485, 910) and also at a switchback on the Springs Creek road (GR 515, 919). It consists of thin bedded (5 to 20 centimetre) dark-grey to black limestone, with varying amounts of quartz sand and silt supported by a calcite matrix, and thin calcareous quartz-arenite interbeds. The sandy limestones contain coarse unlaminated to cross-laminated quartz sand which grade upward into sparse quartz sand and silt in a fine-grained calcareous matrix. Upper parts of beds commonly contain evidence of recrystallization to coarse-crystalline calcite which shows a very characteristic 'beef' texture.

Packages of dark grey carbonates occur at higher levels in the stratigraphy in the more thickly developed sequences as found on Mount Bruce and the ridge between Mount Bruce and the Paradise mine. The two small peaks north and northwest of the Paradise mine (GR 414, 917 and 485, 915 respectively) are composed of this black carbonate facies which forms positive weathering features.

SILTSTONE-ARGILLITE LITHOFACIES - Hh 2

The siltstone-argillite lithofacies comprises thick sequences of thin bedded (1 to 10 centimetres) graded siltstone and argillite and finely laminated (1 to 5 millimetres) black, dark to light green and grey argillite (without siltstone). This lithofacies comprises the bulk of the Horsethief Creek Formation and is also interbedded within the other main lithofacies. The graded siltstone-argillite couplets are interpreted as distal turbidites, and the laminated argillites as pelagic deposition of fine clays.

DOLOMITE - Hh 3

A buff dolomite, up to 30 metres thick, occurs in the lower part of the sequence. This is best observed on the ridge north of the Paradise mine (GR 498, 922) where it forms crags and a cliff which extend into Bruce Creek (Figure 29, in pocket). It is developed in all sections of the Horsethief Creek Formation, including Red Line Creek where the entire Horsethief Creek Formation attains a thickness of only 80 metres. Dolomite supported quartzite and dolomite pebble-conglomerate beds, in which the dolomite matrix has recrystallized to a sparry cement, occur in Springs Creek (GR 514, 920).

QUARTZ FELDSPAR ARENITES AND PEBBLE CONGLOMERATES - Hh 4 (Grit)

Thick sequences of Horsethief Creek grit give rise to the flat easternmost summits of the Purcell mountains in the Invermere area, but they are most easily accessible on the Horsethief Creek road where they outcrop on both sides of the bridge spanning Horsethief Creek (GR 495, 027) (Figure 1).

The pebble conglomerates consist of grain-supported, moderately-sorted crystalline quartz and quartz-feldspar clasts with varying amounts of characteristically red jasper, together with green to grey argillite, quartzite and dolomite lithoclasts. A matrix, comprising less than 20 per cent of the conglomerates, is composed of quartz, feldspar, lithic clasts, carbonate, sericite and chlorite. Quartz and jasper grains are usually about 1 to 2 centimetres but may exceed 10 centimetres in length. In general feldspar grains do not exceed 1 centimetre, and are commonly about half the size of the surrounding quartz grains. Sedimentary structures include normal grading, basal inverse grading, channels and flame structures. They commonly contain isolated boulder size lithoclasts of dolomite and quartzite, and sheet-like argillite rip-up clasts in excess of 1 metre in length.

Sections, 50 to 100 metres thick, contain pebble conglomerate beds between 1 to 3 metres thick and interbedded coarse arenites and argillites. Individual beds have a lenticular geometry at the outcrop scale but pinch out over distances of 20 to 100 metres (Figure 10).

Coarse arenite beds are compositionally equivalent to the pebble conglomerates but are generally poorly sorted and have a greater proportion of matrix. In thin section, quartz grains characteristically display abundant inclusion trails and strain extinction and the matrix consists of quartz arenite, argillite lithoclasts, sericite, chlorite, muscovite and dolomite rhombs. Chlorite, muscovite and dolomite grains are euhedral and exhibit overgrowth relationships. The feldspar is always strongly altered, although albite twinning ghost-textures are present.

RED AND VARICOLOURED ARGILLITES - Hh 5

Red and varicoloured argillites occur at the top of the Horsethief Creek Formation. They outcrop along the Horsethief Creek road just east of the bridge (GR 497, 026) but are best exposed at the eastern ends of the ridges on either side of Law Creek. The sequence comprises red, green, pink, purple and buff argillites with interbedded packages of pink carbonate, and varicoloured impure arenites.

LOWER PALEOZOIC

The Lower Paleozoic succession consists of the Lower Cambrian Cranbrook Formation, Middle

Cambrian Jubilee Formation and the Ordovician-Silurian Beaverfoot Formation. The only location where Lower Paleozoic strata have been identified is on Law Ridge immediately south of Horsethief Creek. The succession is readily correlated with Lower Paleozoic strata in type sections on Mount Forster and Jubilee Mountain to the northeast (Reesor, 1973).

Each of the Lower Paleozoic formations is unconformity bound and tapers westward onto the Windermere high, reflecting continued activity in the Lower Paleozoic (Reesor, 1973; Figure 3).

CRANBROOK FORMATION - Cc LOWER CAMBRIAN

The Cranbrook Formation used herein corresponds to the unit described by Reesor (1973) below the Jubilee Formation south of Horsethief Creek. At this location the Cranbrook Formation lies gradationally, and with apparent conformity upon the Horsethief Creek Formation, and attains a thickness of between 5 to 10 metres. It comprises poorly bedded dolomite-supported coarse quartz arenite and pink-buff fine-grained dolomite with quartz arenite laminations and dispersed quartz granules.

JUBILEE FORMATION - Cj MIDDLE CAMBRIAN

The Jubilee Formation is a poorly bedded pale-cream, white to pink weathering cliff-forming dolomite. It consists of finely laminated (1 to 5 millimetres) dolmicrite, with common disturbed layers and detrital laminations of reworked micritic laminations. It attains a thickness of only 50 metres on Law Ridge but thickens rapidly northwards to Mount Forster where it is approximately 400 metres thick (Bennett, 1985). The Jubilee Formation is characterized by dissolution and recrystallization textures resulting from karsting.

BEAVERFOOT - OSb ORDOVICIAN-SILURIAN

The Beaverfoot Formation overlies the Jubilee Formation with apparent conformity on the north side of Law Creek. At this location it attains a thickness of approximately 20 metres and comprises blue-grey fossiliferous micritic limestone and dolomite. The Beaverfoot Formation is characterized by very distinctive pale-grey weathering and well developed bioturbation which, when enhanced by differential weathering, imparts a mottled appearance.

UPPER PALEOZOIC

The Upper Paleozoic succession consists of the Middle Devonian Mount Forster Formation and the Upper Devonian Starbird Formation (Norford, 1981). Upper Paleozoic strata are exposed in the core of the Mount Forster syncline on Law Ridge, as a major inlier in the footwall of the Mount Forster fault in Delphine and McDonald creeks and as a small inlier in the immediate footwall of the Delphine fault in Delphine Creek (Figures 2 and 29). The Law Ridge section has been described by Reesor (1973) and can be correlated with Upper Paleozoic sections to the northeast.

At least two formations are present. An upper succession of black crinoidal limestones exposed on Black Diamond Mountain correlate unequivocally with the Starbird Formation on Starbird Ridge north of Horsethief Creek. However, the lower succession of quartzites and dolomite supported quartz grits are anomalous, initially having been correlated with the EoCambrian Hamill grits on lithological grounds (Root, 1983) and then with the Mount Forster Formation on the basis of derived fossiliferous clasts from the Beaverfoot Formation (Root, 1985; used herein).

MOUNT FORSTER FORMATION - Dmf

The Mount Forster Formation in the Law Creek section is dominated by red, green, pink, and buff argillites, with lesser amounts of interbedded dolomites and impure sandstones. Many of the argillites are calcareous and dolomitic. Bed thicknesses are highly variable from about 5 centimetres to over 1.5 metres. Calcretes and the generally red colouring indicate a well drained and oxygenated environment (Burley *et al.*, 1985).

The Mount Forster Formation in the Delphine inlier consists of two units. The lower unit is a well bedded (10 to 50 centimetres) sequence of dolomites, dolomite supported quartz-arenites and buff to pink dolomite which contains irregular distributions of isolated and laminated quartz granules and arenites (map unit Dmf 1, Figure 29). This unit is lithologically identical to the Cranbrook Formation exposed on Law Ridge. Unconformably overlapping this unit westwards is an upper sequence of well bedded (0.5 centimetre to 1 metre) internally tabular crossbedded, medium to coarse, pure, well-sorted quartz arenites (map unit Dmf 2, Figure 29). The upper quartzites are documented only in the Shamrock Lake and Delphine Creek areas, (Figure 1).

STARBIRD FORMATION - uDs (SHAMROCK LAKE INLIER)

The Starbird Formation consists of well-bedded, calcareous quartz sands and silts, black carbonaceous, argillaceous, stromatoporoid limestone and black crinoidal calcarenites. It lies above the Mount Forster Formation with westward stepping angular unconformity in the Shamrock Lake area. At the base of the Starbird Formation are locally developed angular limestone boulder breccias which are interpreted as the equivalent of fore-reef talus cones to overlying stromatoporoid and crinoidal bioherms.

STRUCTURE

INTRODUCTION

The structural data are presented in the form of a 1:50 000 map (Figure 29, in pocket) accompanied by 8 serial cross sections (Figure 30, in pocket). The Toby-Horsethief Creek area comprises three major thrust sheets; the Mount Nelson sheet, the Mineral King sheet and the Mount Forster sheet (Figures 11 and 12). Of these, the Mount Nelson sheet is further sub-divided into four major fault panels, giving a total of six major fault panels within the map area (Figure 11).

MOUNT NELSON THRUST SHEET

The Mount Nelson sheet is dominated by the Mount Nelson-Mount Forster anticline-syncline pair, which has a wavelength of approximately 15 kilometres and an amplitude of 5 kilometres, and is interpreted to be a leading anticline-syncline fold pair generated by a frontal ramp on the underlying Purcell fault. Since the detachment horizon of the underlying Purcell fault is not known, its position has been approximated using the kink geometry of the Mount Nelson anticline - Mount Forster syncline fold pair (Figure 12), and Cordilleran Transect Lithoprobe data (Cook *et al.*, 1987). The Mount Nelson sheet comprises a package of easterly vergent imbricate thrust panels, complicated in the Delphine panel by a westerly vergent package of backthrusts (Figure 12).

MINERAL KING THRUST SHEET

The Mineral King sheet overthrusts the Mount Nelson sheet on the Delphine fault and truncates the westerly vergent structures of Mount Catherine ridge (Figure 1) in its footwall. The western region of the Mineral King sheet is dominated by an easterly verging package of fault bound panels, known as a duplex (Dahlstrom, 1970), in the footwall of the Mount Forster fault. This is referred to as the Mineral King duplex system (Figures 29 and 30). Duplexes of different scales are observed along the length of the footwall to the Mount Forster fault, from the minor horses of Horsethief Creek and Mount Forster formations exposed at Shamrock Lake to the major Mineral King duplex system (Figure 29).

MOUNT FORSTER SHEET

The Mount Forster sheet overthrusts the Mineral King sheet on the Mount Forster fault and is plugged by the Late Cretaceous [108 Ma, Reesor (1973)] Horsethief Creek granite batholith. The Mount Forster fault is rooted in a steeply dipping, north trending zone along the eastern edge of the Kootenay Arc, southwest of Toby Creek, from where it steps, in a series of ramps and flats, northeast across the Toby-Horsethief creek map area, to Starbird Ridge.

DEFORMATION PHASES

Four major deformations have been recognized (Table 1), Helikian-Devonian extension (D_1), Jurassic-Paleocene contraction (D_2-D_3) and Eocene extension (D_4).

HELIKIAN TO DEVONIAN EXTENSION

The D_1 extensional deformation has been subdivided into D_{1a} Helikian, D_{1b} Hadrynian and D_{1c} Devonian which were recognized from the following criteria:

- Regional and local sedimentary facies variations.
- Direct observation of extensional faults.
- Level of unconformities in adjacent fault panels.
- Stratigraphic thickness changes across faults.

D_{1a}: The D_{1a} deformation is reflected by the regional Dutch Creek and Mount Nelson formation basal unconformities and intraformational unconformities within the Mount Nelson Formation, for example the informal Mount Nelson-Frances Creek boundary of Bennett (1985). The Nelson Creek fault (Figure 2, 11) across which the Dutch Creek Formation changes in thickness by up to 600 metres (Figure 30) is the best example of a D_{1a} fault.

D_{1b}: The principal manifestation of D1b deformation is the Windermere unconformity, which cuts across different stratigraphic levels of the underlying Belt-Purcell Supergroup within adjacent fault blocks. This has led to the interpretation of the basal Windermere Toby Formation as a syn-rift deposit (Pope, 1989), which is in agreement with recent sedimentological facies analysis by Bennett (1985). The D_{1b} deformation accounts for most of the apparent D_1 extension, but this may in part reflect the relatively good preservation of the Windermere unconformity compared to the Lower and Upper Paleozoic sequences which have been either largely eroded or were not deposited in the Toby-Horsethief Creek area. A good example of a D_{1b} fault which detaches in dolomitized halite beds of the white marker sequence is exposed on the northeast face of Mount Law (Figure 27).

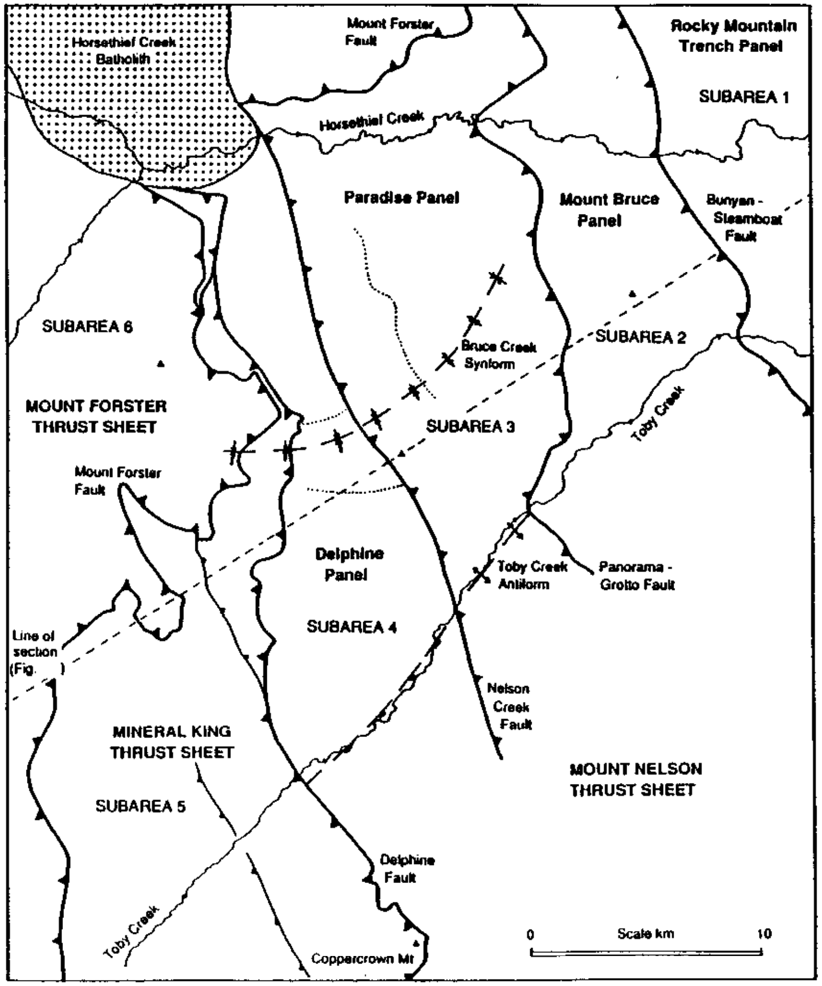


Figure 11. Summary structural map of Toby-Horsethief Creek area.

TABLE 1. SUMMARY OF DEFORMATION PHASES

EVENT			STYLE OF DEFORMATION
D_4		a)	Through-going high angle extension faults.
EOCENE EXTENSION		b)	Extensional reutilisation of D_1, D_2 and D_3 faults.
D_3		d)	F_2 folds and S_2 axial planar penetrative foliation locally developed in footwall ramps of major thrust sheets.
COLUMBIAN PROGRESSIVE DEFORMATION		c)	Foreland propagating duplexes in collapsed footwall ramps of the major thrust sheets.
D_2		b)	Hinterland propagation of major thrust sheets.
		a)	East vergent S_1 penetrative foliation (normally slaty cleavage) and F_1 buckle folds.
D_1	D_{1c} Devonian		
EPISODIC EXTENSION			Thickness and facies changes across faults.
OF THE	D_{1b}		Hadrynian Changes in levels of unconformities
PASSIVE MARGIN			Directly observed extensional faults
	D_{1a} Helikian		

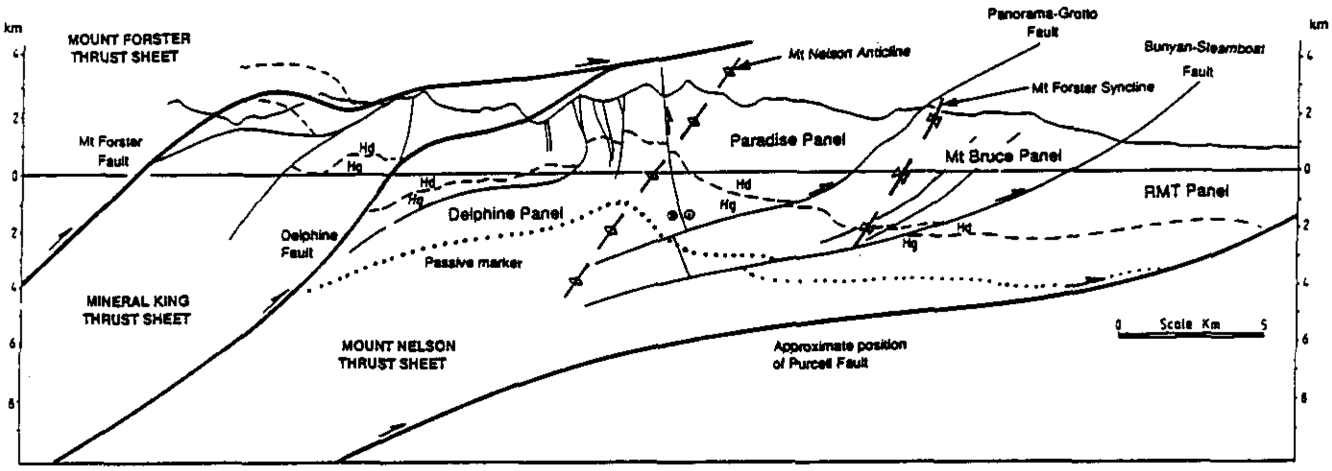


Figure 12. Summary cross section of Toby-Horsethief Creek area.

D_{1c}: D_{1c} deformation is indicated by the thinning of Paleozoic strata westward onto the Windermere high (Reesor, 1973) and the development of small fault bound sub-basins over the crest of the Windermere high (Root, 1983; Pope, 1989), in the Delphine Creek, Shamrock Lake and McDonald Creek areas.

D_2-D_3 JURASSIC-PALEOCENE 'COLUMBIAN-LARAMIDE' *CONTRACTION*

D_2-D_3 contraction had a southwest to northeast tectonic transport direction. An S_1 foliation was developed initially by layer-parallel shortening and subsequently through F_1 buckle, fault propagation and fault-bend folding and thrust faulting. The formation of the S_1 foliation was accompanied by regional progressive metamorphism up to lower greenschist facies in the west and sub-lower greenschist facies in the east of the Toby-Horsethief Creek area.

The three major thrust sheets propagated towards the hinterland subsequent to the development of S_1 F_1 folding, such that they cut down-section locally in their hangingwall and footwall panels, [as noted by Freiholz (1983) for the Mount Forster fault in the Red line Creek area] and overprint footwall ramp zones with an S_2 foliation and F_2 folding. The thrust sheets are therefore 'out of sequence' (Butler, 1982) with respect to the classic foreland propagating thrust sequencing proposed by Rich (1934), and have the smooth, planar trajectories typical of out-of-sequence faults (Cooper and Trayner, 1986; Morley, 1988).

Footwall ramp areas of the major thrust sheets have collapsed, resulting in the formation of numerous major and minor foreland propagating duplex systems which locally fold their hangingwall panels (for example the Mineral King duplex system and the Delphine fault footwall duplexes, Figure 30, Sections 6 and 5 respectively). The out of sequence thrusting and associated S_2 F_2 folding and duplexing is postdated by the Horsethief Creek batholith which plugged the last-to-move Mount Forster fault (Foo, 1979) at 108 Ma (Reesor, 1973).

D_4 EOCENE EXTENSION

Eocene extension is manifested by the extensional reutilization of thrust faults and by high angle brittle extension faults (Pope, 1989); the latter are the youngest tectonic structures seen in the Toby-Horsethief Creek area. A characteristic feature of these Eocene faults is the presence of ferroan dolomite in the fault zones.

IGNEOUS ROCK TYPES

INTRODUCTION

Five suites of igneous rocks have been identified in the Toby-Horsethief Creek map area. These are:

- Toby Volcanics — Hadrynian, 760 Ma
- Green metadiabase dikes — Hadrynian, 760 Ma (?)
- Andesitic volcanic flows and tuffs — Middle Devonian
- Potassic ultrabasic (kimberlitic) dikes — Permo-Triassic, 245 Ma
- Horsethief Creek granite batholith — Middle Cretaceous, 108 Ma

Of the above igneous rock suites; the Toby volcanics have been analysed and described in detail by Bennett (1985), and the Horsethief Creek granite has been studied in detail by Reesor (1973). All igneous rock suites except the Horsethief Creek granite are strongly altered.

TOBY VOLCANICS

The Toby volcanics are a sequence of submarine volcanics believed to be related to the regional D_1 Hadrynian extension of the passive margin (Bennett, 1985; Pope, 1989). A thick sequence (200 metres) of Toby volcanics (Bennett, 1985) is locally developed on Starbird Ridge at the base of the Toby Formation. They constitute a series of major submarine basalt flows comprising crackle breccias, massive pillow lavas and hyaloclastites.

Near the contact between the Toby and Horsethief Creek formations on the ridge north of the Paradise mine (GR 485, 910) a very thin (10 to 20 centimetres) vesicular lava may be traced over short distances. This lava is informally named the Paradise Ridge flow. The Toby Formation in this vicinity consists of diamictite flows and attains a thickness of only 80 metres.

The Paradise Ridge flow is a plagioclase-phyric glomerocrystic holocrystalline basaltic andesite with a fine-grained plagioclase groundmass. The plagioclase, as with the Toby volcanics, is too altered and fine grained to determine composition by optical means, thus precluding a precise name, but the texture is suggestive of basaltic or andesitic composition. The Paradise Ridge flow is correlated with the Toby volcanics, to the north, on the basis of petrography and early syn-D_{1b} extensional setting (Pope, 1989).

GREEN METADIABASE DIKES

The green metadiabase dikes are correlated with the Toby volcanics on the basis of field relationships, petrology and whole rock geochemistry (Pope, 1989). These dikes are the most commonly seen igneous rocks in the Toby-Horsethief Creek area; they are easily traced on 1:15 000 aerial photographs and are commonly up to 20 metres thick.

The green dikes always appear to be approximately perpendicular to bedding. This relationship suggests they were intruded into relatively undeformed sub-horizontal strata, indicating that they are probably associated with the early episodes of D_{1b} Hadrynian extension, prior to any significant amount of extensional folding. That the dikes are syn-D_1 structures is further shown by their ubiquitous association with faults, which are demonstrably of D_{1b} Hadrynian origin (Pope, 1989).

The dikes have narrow zones of contact metamorphism characterized by loss of colour in the country rocks, and pyrite spotting. In some places small amounts of copper mineralization are associated with the dikes, in particular the Silver Queen mine in Law Creek and the Black Diamond mine in Toby Creek (Figure 31).

The dikes consist of coarse to fine-grained anhedral masses of chlorite, anhedral to euhedral carbonate and sericite, and skeletal opaque minerals. Very little of the primary mineralogical and textural features remain, but in some samples albite twinning and seriate feldspar ghost textures are common in the sericitic domains. Many samples show chlorite pseudomorphs after pyroxene or amphibole. In the more heavily altered dikes a strong S_1 foliation defined by remobilized chlorite and white mica partially to completely obliterates these textures. The bulk proportions of chlorite, sericite and carbonate, indicate that the dikes were originally basaltic in composition.

DEVONIAN VOLCANICS

Devonian volcanics are hosted in the Dmf 1 member of the Mount Forster Formation the Shamrock Lake and Red Line Creek areas. No definitive evidence of chilled bases and weathered tops was identified in this study in order to state categorically that the volcanics are flows rather than sills, but the identification of pillows by Root (1985) indicates the former. In the McDonald-Red Line Creek area, dark green highly altered mafic tuffs, consisting of foliated chlorite and carbonate, occur in the mineralized package of stratigraphy constituting the Redmac deposit. The tuffs may be traced intermittently above the tree line towards the Red Line glacier in the immediate footwall of the Mount Forster fault.

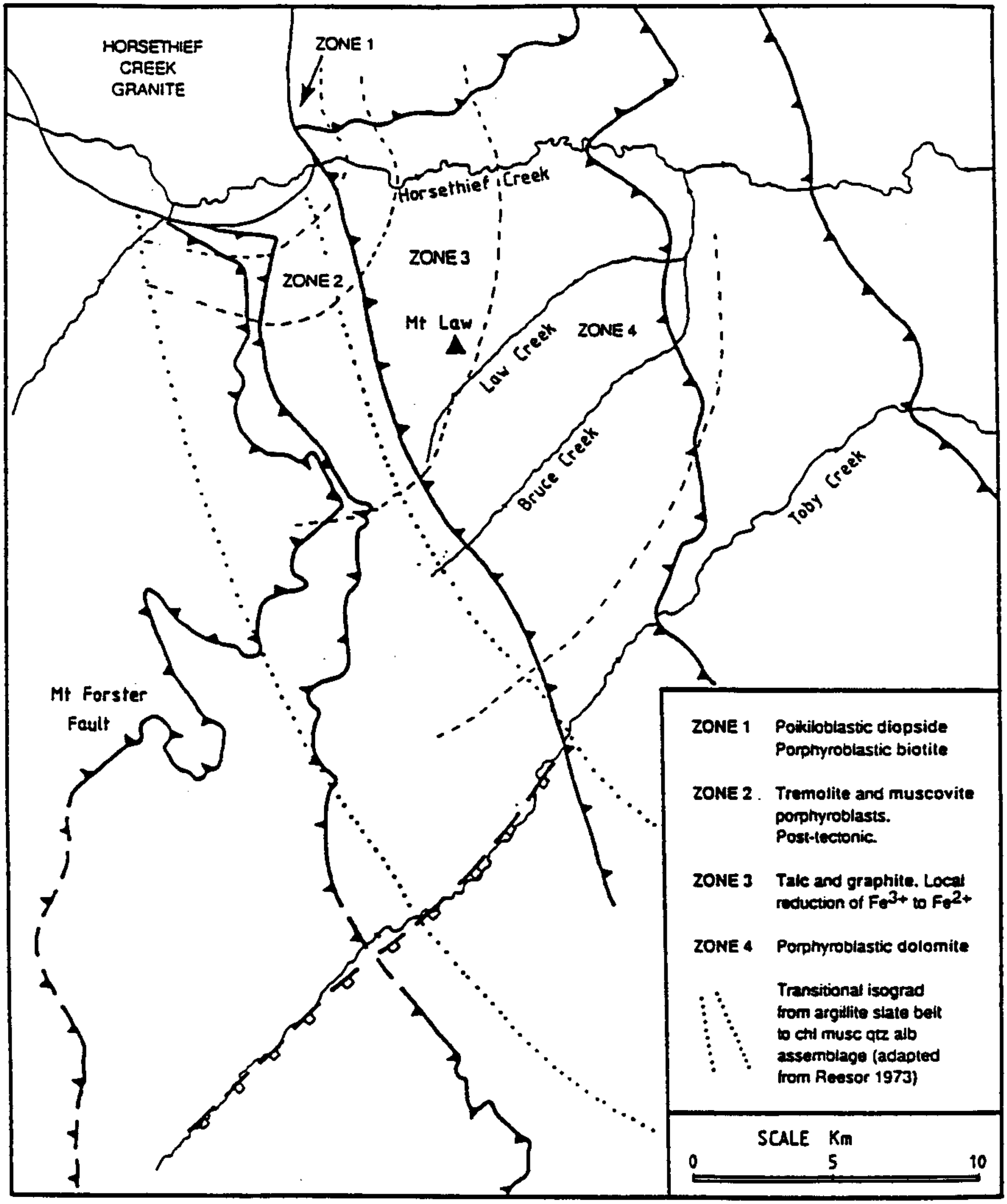


Figure 13. Contact metamorphic zones associated with the Horsethief Creek granite.

The Shamrock Lake volcanics are totally altered and highly strained due to their position in the immediate footwall of the Mount Forster fault. They consist of approximately 20 to 30 per cent opaque material, 70 per cent carbonate and less than 10 per cent muscovite, fine grained quartz and sericite. The opaque material generally has a chicken wire type of texture, surrounding small domains of the carbonate matrix. This texture is thought to result from the complete alteration and recrystallization of the volcanics. Vesicles have highly deformed shapes which are outlined by euhedral muscovite and are full of anhedral to euhedral coarse grained carbonate.

LAMPROPHYRIC TO KIMBERLITIC DIKES

A suite of lamprophyric to kimberlitic dikes occurs in a north trending belt corresponding to the position of condensed sequences of Hadrynian and Paleozoic strata marking the present locus of the dismembered Windermere high. The dikes typically occur as narrow sheets from 50 centimetres up to approximately 10 metres wide. They have narrow chilled margins and do not show evidence of contact metamorphism either with the country rocks or the xenoliths they contain. This indicates that they were rapidly intruded and that they cooled quickly.

Many of the dikes are partially to almost totally carbonated and they are characterized by a rusty brown, deep weathering profile. The dikes have been subdivided on the basis of petrology and chemistry (Le Maitre, R.W., 1989 and Foley *et al.*, 1987) into suites showing lamprophyric to kimberlitic affinities and a group of true kimberlites (Pope, 1989).

- The lamprophyric-kimberlitic dikes are light green, with a carbonate matrix and abundant carbonate pseudomorphs after euhedral olivine phenocrysts. Phenocrysts of phlogopite may be present in abundance or absent. These dikes frequently exceed 50 per cent xenoliths by volume, which are typically from the underlying Belt-Purcell assemblage, but granitic gneiss and ultrabasic xenoliths are also documented.
- The kimberlitic dikes are dark green, with distinctive dark green phlogopite phenocrysts, commonly 1 to 3 centimetres and occasionally in excess of 8 centimetres long, and apatite phenocrysts up to 0.5 millimetres across poikilitically enclosed by phlogopite. The matrix consists of carbonate, serpentine, chlorite, apatite and an unidentified opaque phase. The xenolith content of these dikes is normally less than 10 per cent by volume.

HORSETHIEF CREEK GRANITE

The Horsethief Creek granite is one of a series of large quartz monzonites intruded between 122 to 94 Ma (Höy and Van der Heyden, 1988). The Horsethief Creek granite has been mapped, dated (108 Ma), analysed and petrographically studied by Reesor (1973).

In the Toby-Horsethief Creek area the main granite has not been observed south of Horsethief Creek, but large granite and aplitic apophyses, associated with minor skarn mineralization are exposed at the northern end of the McDonald Creek logging road, (Figure 1).

Field evidence from the Toby-Horsethief Creek area suggests that the Horsethief Creek granite is post-kinematic. It appears to plug the Mount Forster fault (Figure 29) although the contact is not exposed south of Horsethief Creek, and is surrounded by concentric contact metamorphic zones (Figure 13) which would be disrupted by faults if the granite was syn or pretectonic.

There is evidence of contact metamorphism up to 10 to 15 kilometres from the granite in an easterly to southeasterly direction but south of the granite the westerly increasing grade of regional metamorphism in the Purcell anticlinorium masks the effects. (Figure 13).

ZONE 1

Zone 1 contains poikiloblastic diopside, and porphyroblastic biotite. The diopside occurs as large anhedral networks in optical continuity, surrounding quartz. Actinolite, olivine, diopside and garnet occur within calcareous siltstones of the Dutch Creek Formation at the granite contact in the McDonald Creek area.

ZONE 2

Tremolite porphyroblasts have partially to completely replaced the Hg 2 dolomite member of the Lower Gateway Formation at the northeast end of McDonald Creek, (these have a characteristic rosette or bow tie shape and were noted by Walker, 1926). Post-tectonic muscovite porphyroblasts occur slightly farther from the granite in the Hmn 3 dolomite member of the Mount Nelson Formation at the northeast end of McDonald Creek. Most muscovite porphyroblasts show mimmetic growth in the phyllosilicate orientation inherited from the S_2 foliation, but many others in less phyllosilicate rich domains are randomly orientated and clearly post-date the S_2 foliation associated with the latest movements on the Mount Foster fault.

ZONE 3

Zone 3 is of much greater extent than zones 1 and 2 and is harder to define. It is characterized by a qualitative loss of colour in the rocks of the Mount Nelson Formation. This occurs particularly well in the Hmn 4 purple sequence which, in the Red Line Creek and Law Creek areas, has lost its distinctive red-purple colour and is instead, pale grey, green or brown. This is attributed to a reduction in the oxidation state of iron similar to that seen in the contact metamorphic zones of the green metadiabase dikes.

In the vicinity of Mount Law, the carbonaceous interbeds in the Mount Nelson Formation have been metamorphosed to graphite and in the White Marker sequence, magnesite, dolomite and dolomitic siltstones have given way to talc and silica.

ZONE 4

Metamorphism in zone 4 is only apparent on a microscopic scale, manifested by the ubiquitous occurrence of euhedral dolomite porphyroblasts in siltstones and sandstones which have carbonate in the matrix.

MINERAL OCCURRENCES

INTRODUCTION

There are over 80 documented mineral occurrences ranging in size from lead, silver, copper rich veins of less than 4.5 tonnes to the 1.2 million tonne Mineral King deposit. The deposits are located on Figure 31. A summary of data and degree of accuracy in location is indicated in the key. References to Annual Reports of the B.C. Minister of Mines are abbreviated to 'MEMPR AR' in the text and are followed by year of issue.

Four types of mineralization are present: 1) stratabound manto; 2) vein; 3) Mississippi Valley Type (MVT); and, 4) stratiform disseminated. All occurrences are deformed and remobilized to some degree. However, strain has partitioned very inhomogeneously, such that essentially undeformed, primary mineralization and very strongly remobilized mineralization may be observed in a single outcrop. The four main types of mineralization summarized below may be distinguished despite the effects of deformation (Tables 2, 3 and 4). A summary map showing the location of mineral deposits and areas of detailed prospect mapping referred to in the text is shown in Figure 14.

STRATABOUND MASSIVE REPLACEMENT (manto)

This type of deposit, exclusively in dolomites of the Upper Belt-Purcell Supergroup, consists of irregular stratabound bodies of massive, banded and disseminated lead-zinc-silver-iron sulphides which contain minor barium, cadmium and copper. The only significant occurrences in this category (but volumetrically by far the largest producers in the map area) are the 1.2 million tonne Mineral King mine and 24 950 tonne Paradise mine.

MINERAL KING MINE

The Mineral King mine is situated on the north side of Toby Creek (GR 407, 768) approximately 1 kilometre west of the Jumbo Creek fork, at an elevation of 1220 to 1670 metres. The workings consist of a glory hole, two adits, a crushing mill, tailings pond, ancillary buildings and numerous roads, which are spread out over an area of approximately 3 square kilometres. A total of 1 210 000 tonnes of ore were produced before the mine suspended operations in 1964 (MEMPR AR, 1956-1964).

The orebody is hosted by dolomites of the upper Hg 2 member of the Lower Gateway Formation (Figure 15), mapped previously as Mount Nelson Formation by Fyles (1960). The deposit is situated in a high angle fault panel which is part of the Mineral King duplex system in the footwall of the Mount Forster fault (Figure 30, Section 6 and Figure 16). The Dutch Creek Formation and the unconformably overlying Toby Formation occur in the footwall panel of the Mineral King deposit, immediately east of the glory hole.

The present surface expression of the orebody consists of massive pyrite and galena veins in brecciated Hg 2 dolomite around the edges of the glory hole. The glory hole marks the position of the old orebody and is situated in the core of a very tight syncline below a black phyllite. The black phyllite is probably the base of the unconformably overlying Dutch Creek Formation, but there is not sufficient exposure to substantiate this.

The mineral assemblage comprises galena, sphalerite (var. Pribramite), tetrahedrite, pyrite and barite with minor pyrrhotite and chalcopyrite. The tetrahedrite phase contains 6 to 7 per cent silver on average and the sphalerite 1 per cent cadmium (Pope, 1989). Textures may be broadly subdivided into primary and secondary. Primary textures comprise stratabound banding, breccias, space infilling textures and massive (apparently undeformed) coarse grained idiomorphic galena, sphalerite, quartz and dolomite. Secondary textures include deformation banding, grainsize reduction and dynamic recrystallization of galena and sphalerite, brecciation, cataclasis, and transposition of massive ore, and remobilization of ore phases into the S_2 foliation.

PARADISE MINE

The Paradise mine is situated near the head of Springs Creek on the ridge between Springs Creek and Bruce Creek (GR 493, 914) and between 2300 to 2450 metres elevation. The mine area is situated in and above the top of the tree line and exposure is generally good; however, the mine site and stratigraphy is largely obscured by slumped shale from the ridge. The total production was in the order of 24 500 tonnes of lead-zinc-silver ore (MEMPR AR, 1949). Two types of ore were extracted; cerussite (sand carbonate of lead) with an average grade of 6 ounces per ton silver and 6 per cent lead (MEMPR AR, 1901), and galena-cerussite veins with an average grade between 35 to 50 ounces per ton silver and 35 to 50 per cent lead. (MEMPR AR, 1903, 1904, 1916).

TABLE 2. SUMMARY OF PRINCIPAL MINERAL DEPOSITS IN THE TOBY-HORSETHIEF CREEK MAP AREA

	Mineral Deposit	Commodities and Tonnage	Description and Controls
MANTO	Mineral King	1,334,400 tons Pb-Zn ore at 8% Zn and 3% Pb/ton.	Massive replacement in Hg2 dolomite, Hd permeability trap. Remobilised into fold hinge zones in D2-D3.
	Paradise	27,500 tons Pb-Zn ore at 18% Zn, 9% Pb and 7.8 oz/t Ag.	Massive replacement in Hmn7 dolomite, Windermere Unconformity permeability trap, fault remobilisation.
FAULT VEIN	Ptarmigan Group	580 tons Ag-Pb-Fe ore at 200 oz/t Ag	Small Hmn2 dolomite hosted stratabound replacement and major high grade primary fault veins.
	Delphine	200 tons Pb-Ag-Cu (Zn). 150 oz/t Ag 30% Pb and 5.5% Cu.	Massive galena fault vein, 1m wide - 50m long, hosted in Hmn3 dolomite, Windermere Unconformity trap.
	Hot Punch	Approx 200 tons, 40 oz/t Ag and 40%Pb	Fault vein hosted in Hmn3 dolomite below Windermere Unconformity.
	Kootenay Queen Group	<100 tons Ag-Pb-Cu. 35 oz/t Ag and 65%Pb	Fault vein in Hmn3 White Marker dolomite below Windermere Unconformity.
	Silver Queen	Pb-Zn-Cu <100 tons	Metadiabase dike assoc. Hmn2 dolomite hosted veins.
	Pretty Girl Group	Ag-Cu <50 tons	Qtz, cpy tetrahedrite veins in Horsethief Creek Fm.
	Green Ridge	Cu Exploratory workings, no tonnage	Ductile fault zone, qtz cpy veins in Horsethief Creek Fm
FRACTURE VEIN	Copper King/Tatler	Ag-Cu-Pb < 50 tons 10 oz/t Ag 4.5% Cu	Outer arc extension vein system in Hmn3 dolomite anticlinal fold hinge below Windermere Unconformity.
	Silver Spray	Ag-Pb-Cu < 50 tons.	Outer arc extension vein system in Hg2 dolomite below Hd unconformity in anticlinal fold hinge.
	Iron King	Pb-As-Fe. Exploratory Workings	Stratiform Windermere Unconformity related pods and veins of pyrite, galena and arsenopyrite. Hmn5-Hmn6
MVT	Falcon	Zn (Pb-Ag). Prospect status.	Stratabound sphalerite mineralisation in Cj karst system, remobilised into high grade veins in D2-D3.
STRAT FORM	Redmac	Zn (Pb-Ag) Prospect status, diamond drilling program and evaluation by Cominco	Disseminated sphalerite and galena in Dmf1, calcrete groundwater reflux mineralisation?

TABLE 3. EMPIRICAL SUMMARY OF CONTROLS ON MINERALIZATION

MINERAL CLAIMS	COMMODITIES	HOST LITH.		HOST STRATIGRAPHY				PERMEABILITY		STRUCTURE		TYPE OF DEPOSIT			
		Dol.	Clastic	Hg	Hmn	Ht-Hh	Pal.	Ht-Unc	Other	Fault	Fold	Vein	Manto	Dissem	Infill
Bald Eagle	Ag Pb Zn	■			■	■		■				■			
Copper King	Ag Pb Cu Ba	■			■			■			■	■			
Delphine Group	Ag Pb Cu	■			■			■		■		■			
Falcon	Zn Pb Ba	■					■		■						■
Great Northern	Ag Pb Zn Cu	■			■			■			■	■			
Green Ridge	Ag Cu		■			■				■		■			
Grotto	Pb Zn Ba	■					■		■						■
Hot Punch	Ag Pb Zn	■			■			■		■		■			
Iron Cap	Ag (Zn)	■			■			■		■		■			
Iron King Group	Pb	■	■			■		■				■			
Kootenay Queen Group 3	Ag Pb	■			■			■				■			
Last Hope Last Chance	Ag Pb Cu	■			■			■		■		■			
Mineral King	Ag Pb Zn Cu Ba	■	■	■				■		■	■	■	■	■	
Nip & Tuck, Silver Tip 2	Ag Pb Zn	■			■			■		■		■			
Paradise	Ag Pb (Zn Cd)	■			■			■		■		■	■		
Pretty Girl Group	Ag Cu		■			■						■			
Ptarmigan Group	Ag (Pb)	■			■			■		■		■	■		
Red Ledge	Ag Pb Zn		■	■				■		■		■			
Red Line	Ag Pb	■			■			■		■		■			
Redmac	Zn (Ag Pb)	■					■		■					■	
Silver Belt Group 4	Ag Pb (Zn)	■			■			■		■	■	■			
Silver King	Ag Pb	■			■			■		■		■			
Silver Queen Group 3	Ag Pb (Cu Pb)	■			■					■		■			
Silver Spray Group 5	Ag Pb (Cu)	■		■	■				■		■	■			
Sitting Bull Group	Ag Pb	■			■					■		■			
Thunderbird	Pb Zn	■			■					■		■			
Tilbury and BC	Ag Pb	■			■			■		■		■			
Trojan	Ag Cu		■			■						■			
Whiskey Jack	Pb Zn Ba	■					■		■						■
White Cat Group	Ag Pb Zn	■			■				■	■		■			

TABLE 4. SUMMARY OF ORE TEXTURES AND MINERAL PARAGENESIS

Pre D2-D3 Primary Mineralization

Textures	Mineral Assemblage
1 Stratabound irregular manto and banded replacement of primary dolomite associated with solution front volume reduction and collapse breccias.	GALENA
	SPHALERITE (var. Pribramite).
2 Concentrically zoned idiomorphic dolomite and pyrite space infilling overgrowths.	PYRITE
3 Stratabound karstic cavern systems with internally reworked sediments and solution collapse breccias.	PYRRHOTITE
	CERUSSITE
	BARITE

Syn D2-D3 to D4 Deformation, Metamorphism and Granite Intrusion

Microscopic Textures

GALENA
1 Bleischweif (steel galena): Simple shear deformation.

2 Zones of acute grain size reduction - grain boundary sliding and diffusion (Coble creep) processes.

3 Annealed texture with well developed 120° dihedral angles.

4 Folded cleavage pit traces.

PYRITE
1 Shattering and radial point fractures.

2 Hydraulic shattering.

3 Indenting and flattenning and formation of weak foliation.

4 Annealing.

SPHALERITE
1 Deformation bands.

2 Dynamically recrystallised

Mesoscopic Textures

1 Pyrite idiomorph stringers in S2 foliation.

2 Concentration of ore minerals into fold hinges.

3 Hydraulic fracturing and stoping of host rocks and pyrite by remobilised silica, sphalerite, galena, tetrahedrite and boulangerite.

4 Tectonic banding: weak to very strong (mylonitic) transposition foliations.

5 Tectonic breccias and cataclasites.

Mineral Assemblage

	Inclusions
GALENA	Argentiferous Tetrahedrite Polybasite Freislebenite Argentite Native Antimony
ARGENTIFEROUS TETRAHEDRITE	Covellite
BOULANGERITE	
BOURNONITE	Covellite
CHALCOPYRITE	
COVELLITE	
SPHALERITE	Chalcopyrite Disease

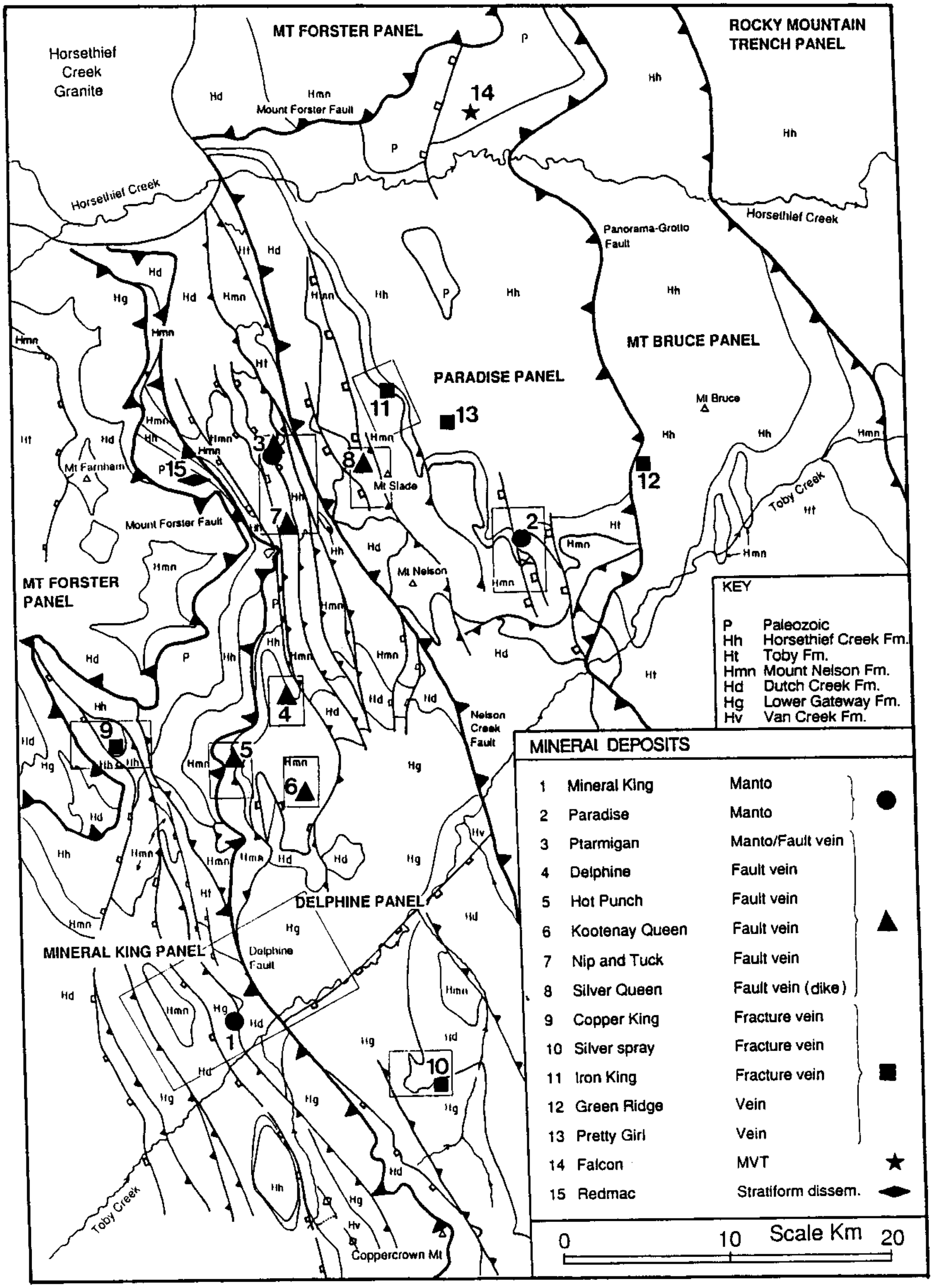


Figure 14. Summary geological map showing location of mineral deposits and areas of detailed prospect mapping referred to in the text. (Note: detailed maps for 7, 12, 13 and 15 are not included in this report.)

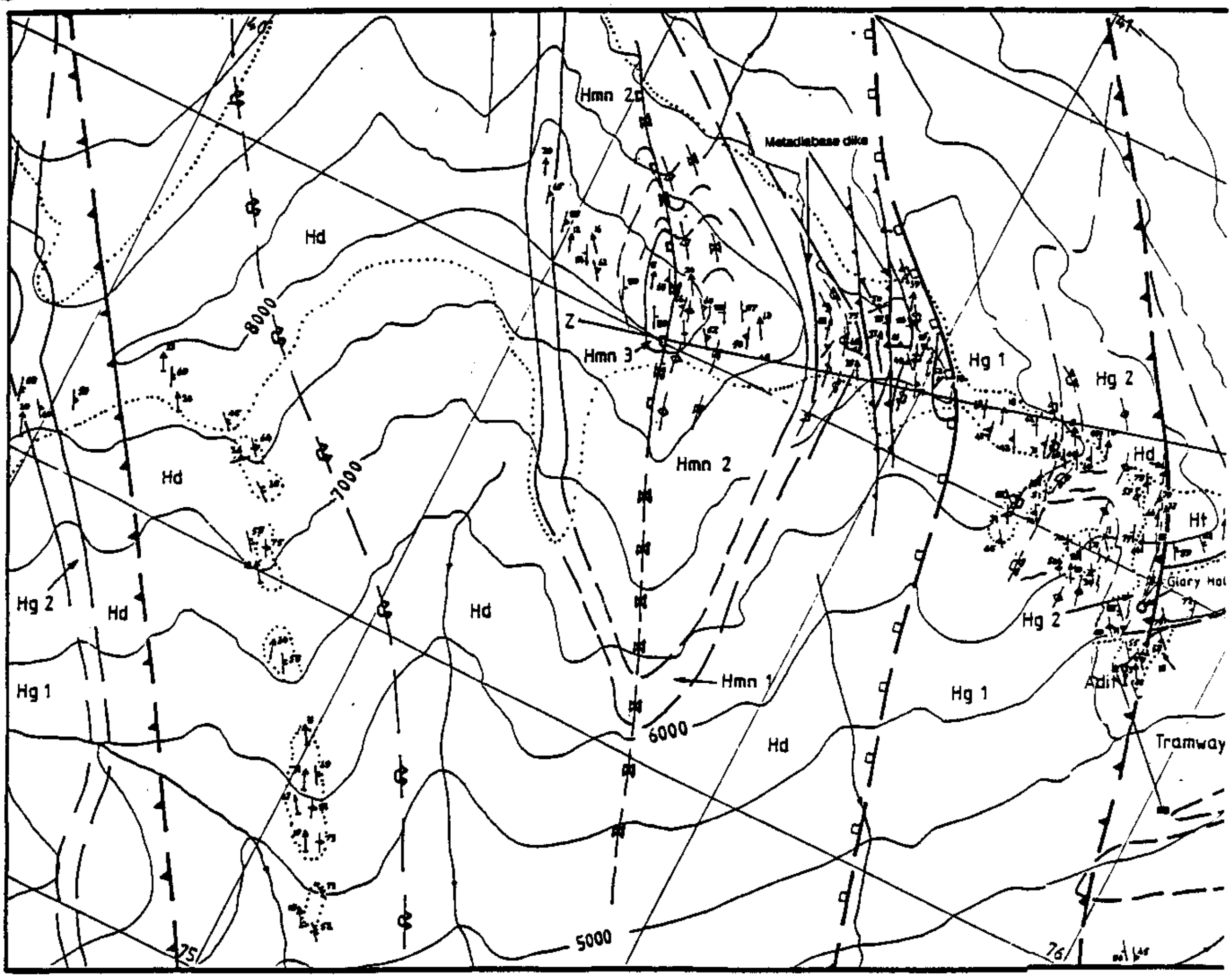


Figure 15. Geological map of the Mineral King mine.

The Paradise mine orebody was within the Hmn 7 upper Mount Nelson dolomite member, immediately below the Windermere unconformity near the core of an east verging anticline which is transected to the west by a fault (Figure 17). Differing thicknesses of the Windermere Supergroup and levels of the Windermere unconformity on either side of the fault indicate that it was active during Hadrynian extension (Figure 17b). The trace of the north-northwest trending fault in the Windermere Supergroup is marked by a number of anastomosing ferroan dolomite and quartz veins. In the hangingwall of the fault, minor outcroppings of very friable Toby Formation limonitic sandstone indicate metalliferous fluids also transgressed permeable lithologies in the hangingwall (Figure 17a).

Samples from the Paradise mine consist of massive panidiomorphic galena, sphalerite, pyrite, sucrosic cerussite and banded dolomite, galena, sphalerite and pyrite. In hand specimens bleischweif texture (steel galena), indicating deformation by simple shear (McClay, 1980) is frequently seen.

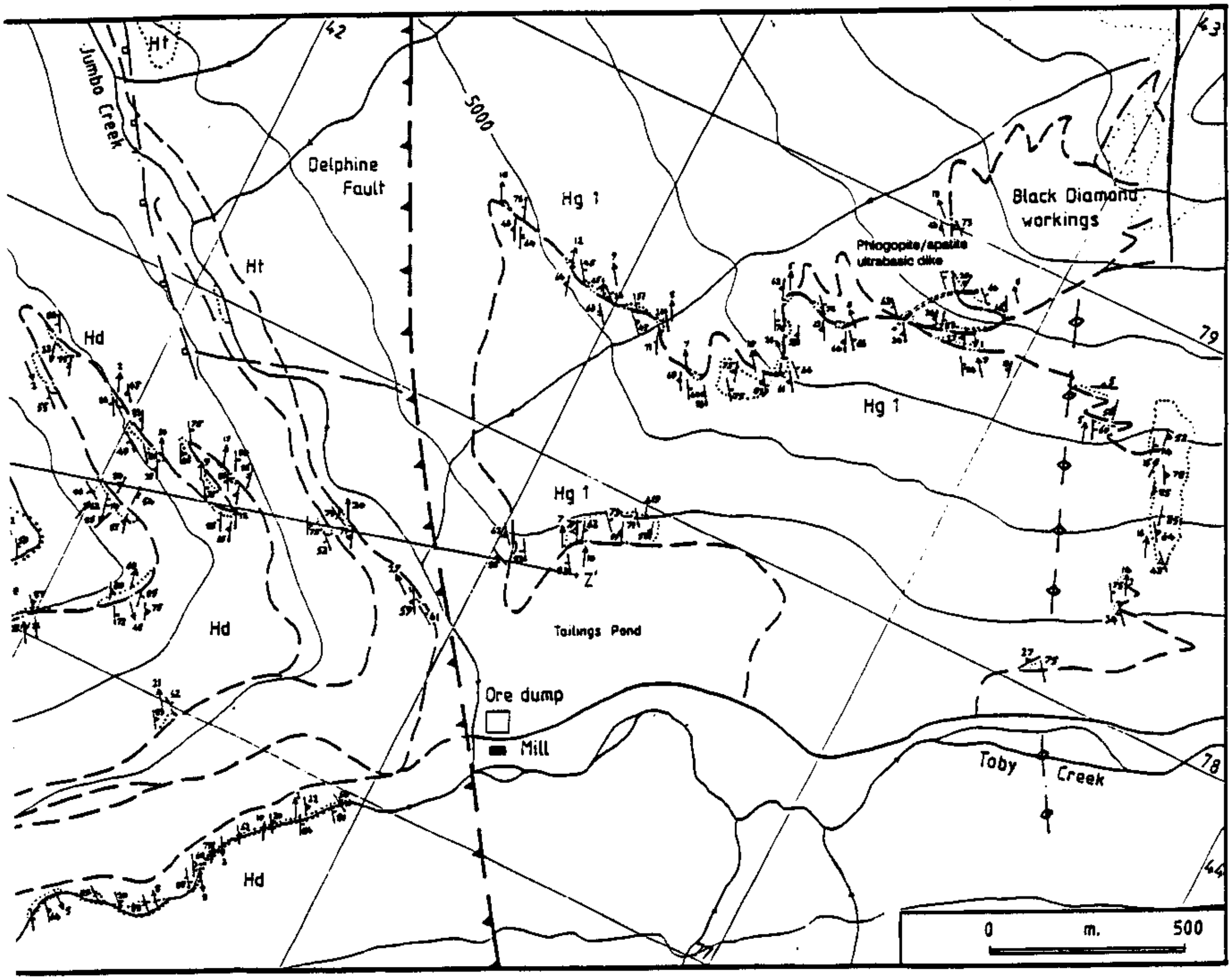
VEINS

Vein mineralization is subdivided into four subcategories:

FERROAN DOLOMITE BRECCIA VEIN SYSTEMS

Ferroan dolomites occur in fault dilation zones and fracture systems as minor veins and net veins to large irregular breccia bodies up to 5 metres across. They commonly form the matrix to fault breccias which can be unambiguously related to D_4 Eocene extension.

The Watch Peak dolomitic breccia (GR 485, 983) is perhaps the best example: ferroan dolomite occurs in a bedding parallel dilation zone in the upper Mount Nelson quartzite and numerous fractures in the overlying Hmn 7 dolomite. It consists of massive coarsely crystalline



ferroan dolomite, vein quartz, minor amounts of siderite and a very small amount of disseminated pyrite. Around the margins of the breccia zone dolomite apophyses penetrate minor fractures and pervasively replace the quartzite. In the upper Mount Nelson dolomite the ferroan dolomite veins react with the host dolomite to form a zone of pervasive silicification (Figure 18). Ferroan dolomite occurrences are frequently associated with galena mineralization, as with the Sunshine and Carbonate showings along the Paradise mine fault (Figures 31 and 17a) and the Iron King deposit, but are more typically barren as in the case of the Watch Peak occurrence.

Stratabound Fault Veins

Discrete tabular bodies of very high grade (in the order of 200 to 450 ounces per ton silver and 60 to 70 per cent lead) lead-silver-copper with subsidiary 1 per cent zinc, comprise tonnages typically in the order of 20 to several hundred tonnes. They are nearly always within dolomites of the Upper Belt-Purcell Supergroup. The principal examples are the Ptarmigan group mines and the Delphine, Hot Punch and Kootenay Queen. A subsidiary group of the fault-vein type are stratabound veins associated with green metadiabase dikes, including the Silver Queen and Black Diamond mines.

PTARMIGAN MINE

The Ptarmigan mine is situated at an elevation of 2600 metres at the head of Ptarmigan Creek (GR 421, 938). It was the major producer of a group of workings belonging to the Ptarmigan group of mines, including the Iron Mask, Silver King and Nip and Tuck. All of these deposits occur along the same fault zone (Figure 19). The Ptarmigan mine produced 520 tonnes of lead-silver-zinc ore, with an average grade of approximately 6.9 kilograms per tonne silver (MEMPR AR, 1921, 1957, 1958, 1959). Mineralization occurred in interconnecting veins of

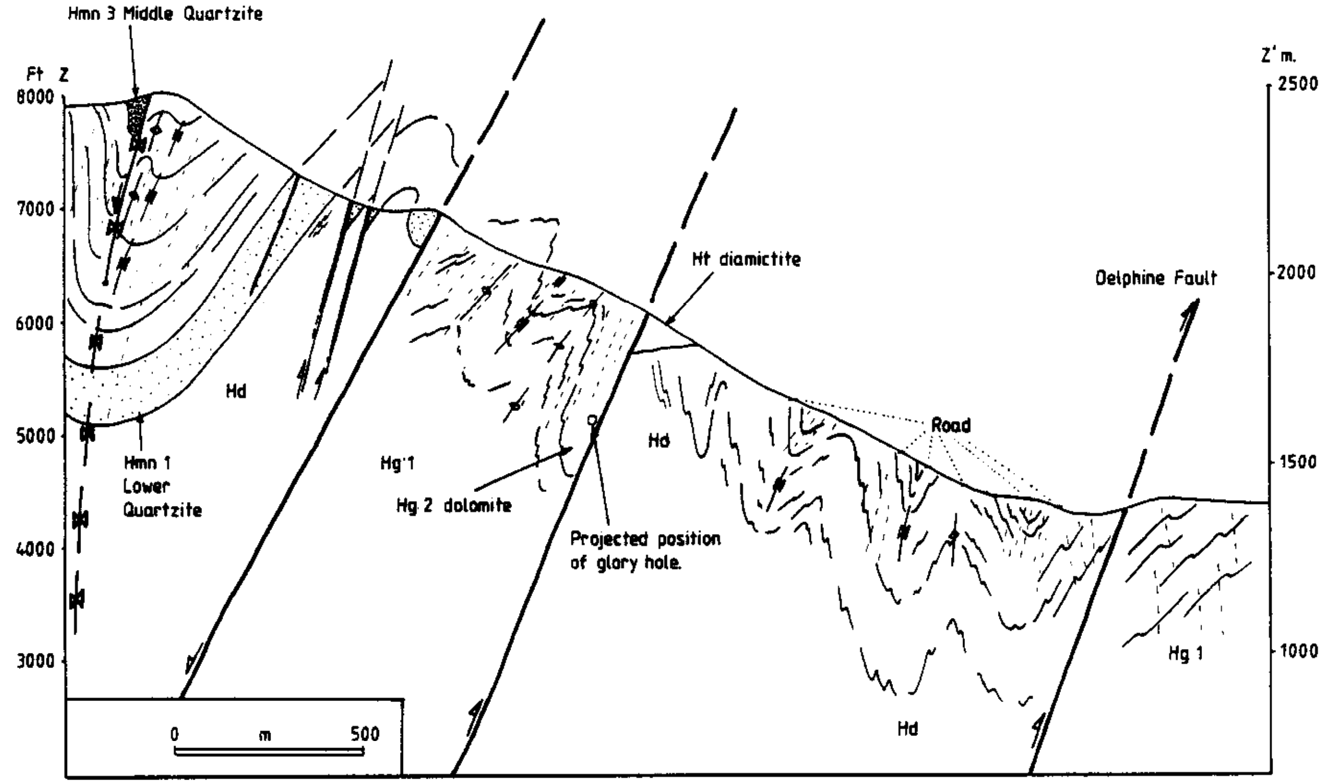


Figure 16. Cross section of the Mineral King mine.

galena and tetrahedrite in quartz, and large pods of pyrite with tetrahedrite (MEMPR AR, 1921).

A field sketch of the south side of Ptarmigan Creek (Figure 20) illustrates the setting of the Ptarmigan workings. They occur within a zone of faults which downthrow Windermere Supergroup to the east against the Hmn 2 Lower Main dolomite in the footwall. Mineralization is best exposed at surface at the main adit entrance (inset Figure 20) where a minor stratabound manto replacement zone of massive crystalline pyrite occurs. The massive pyrite contains a number of randomly oriented minor chert stringers, and major rafts of black chert which have the same orientation as the bedding in the dolomite, along which chert intercalations are found.

All of the mineral occurrences are along faults. They are all situated below the Windermere unconformity or other relatively impermeable members such as the Hmn 3 middle quartzite, in the case of the Ptarmigan main ore zone, and they are all hosted by dolomite.

NIP AND TUCK

The Nip and Tuck is situated in Red Line Creek (GR 422, 924) at an elevation of 2650 metres. It occurs within one of the faults associated with the Ptarmigan Group. The Nip and Tuck, similarly to the Ptarmigan, has a close spatial association with the Windermere unconformity, which projects just above the minesite (Figure 30).

The ore consists of pyrite, galena, tetrahedrite, boulangerite and sphalerite, with grades of approximately 90 grams per tonne silver, 9 per cent lead, 0.7 per cent zinc (MEMPR AR, 1921). The galena has numerous minor inclusions of polybasite, freislebenite and some native antimony. Minor undeformed colloform sphalerite growths and idiomorphic pyrite are considered primary textures, but most of the ore appears deformed with galena, tetrahedrite or boulangerite invading and replacing the primary pyrite.

DELPHINE MINE

The Delphine mine is one of a group of mines situated on the southeast shoulder of Mount Catherine on the north side of Delphine Creek. Situated at an elevation of 1950 metres (GR 422, 862) it was discovered in 1896 and shipped approximately 150 tonnes of lead-silver-copper ore running 2400 to 5000 grams per tonne silver, 20 to 30 per cent lead and 5 per cent copper between 1901 and 1903 (MEMPR AR, 1901, 1904, 1920).

Mineralization comprised a vein of massive galena, 0.3 to 1 metre thick and approximately 50 metres long (MEMPR AR, 1920). Traces of massive galena are present around the edges of the stope, which is up to 2 metres wide. The walls of the stope are smooth and contain patches of strongly weathered and foliated galena which, coupled with the distribution of strata on either side, indicate the mineralization occurs in a fault. The fault dips at 78° towards 060° and has downthrown the upper Hmn 3 white markers to the west, adjacent to a lower part of the white markers in the hangingwall (Fig-

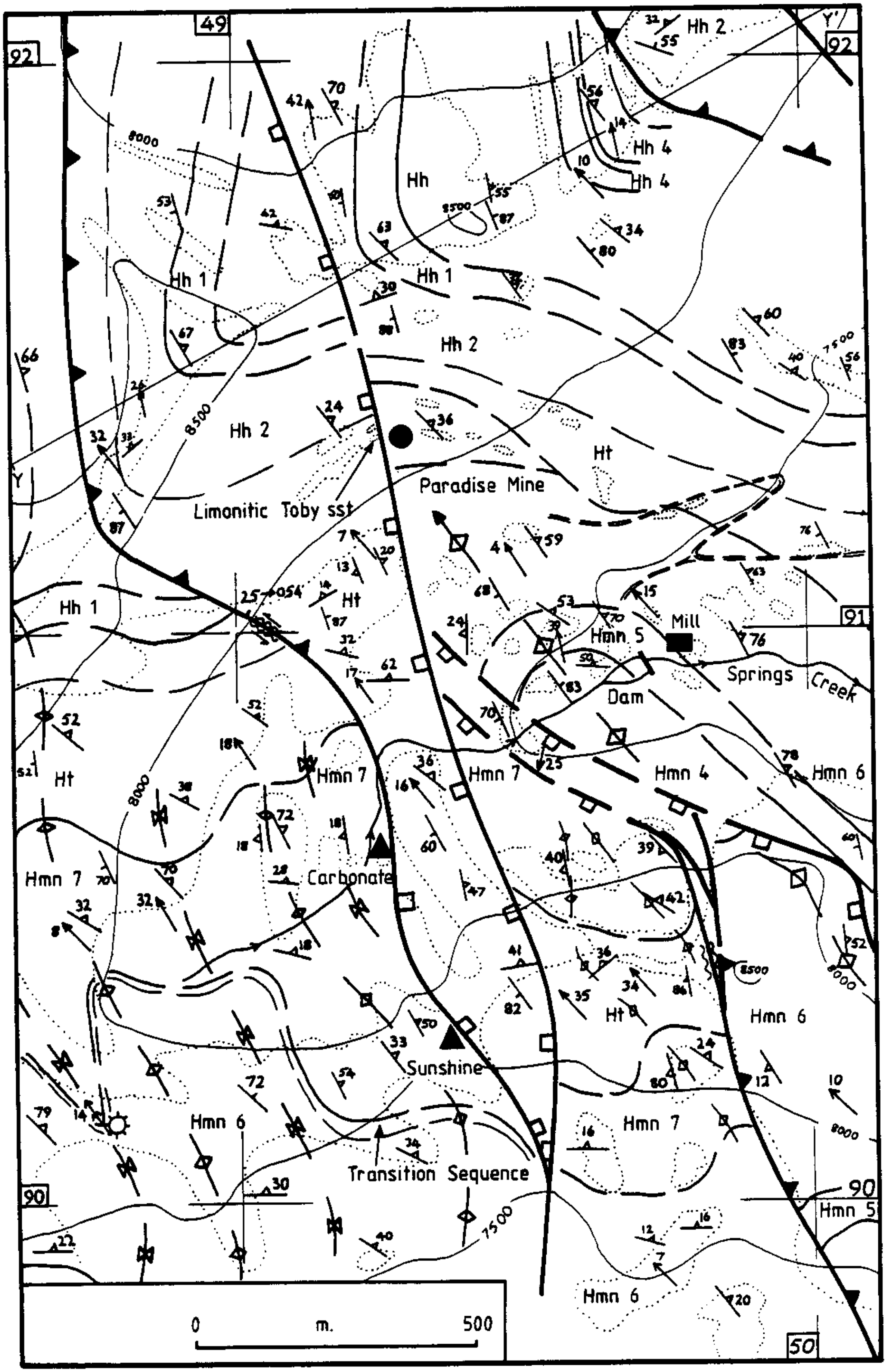


Figure 17a. Geological map of the Paradise mine.
(Symbols and stratigraphic notation as for Figures 29 and 30.)

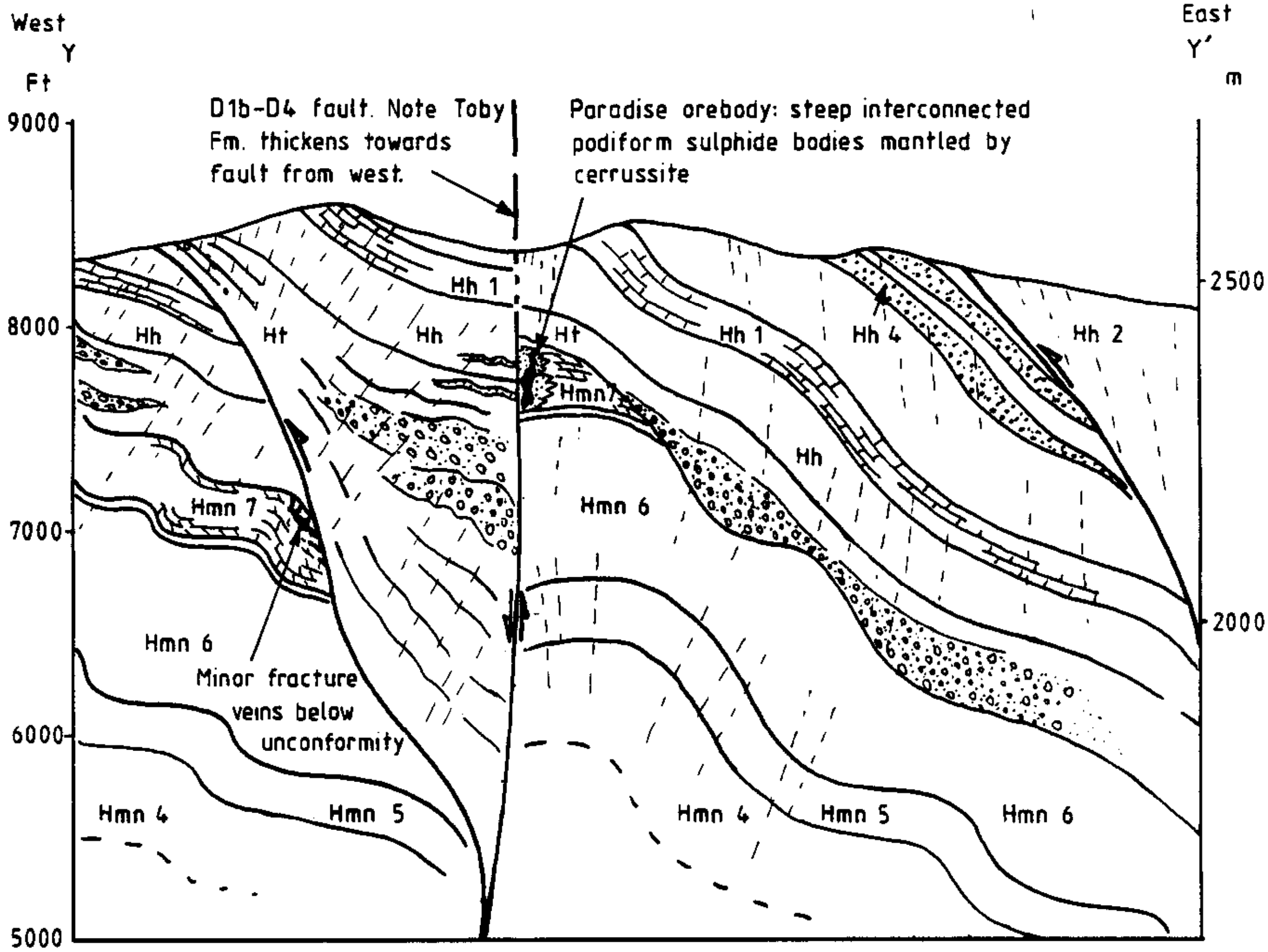


Figure 17b. Geological cross section of the Paradise mine.

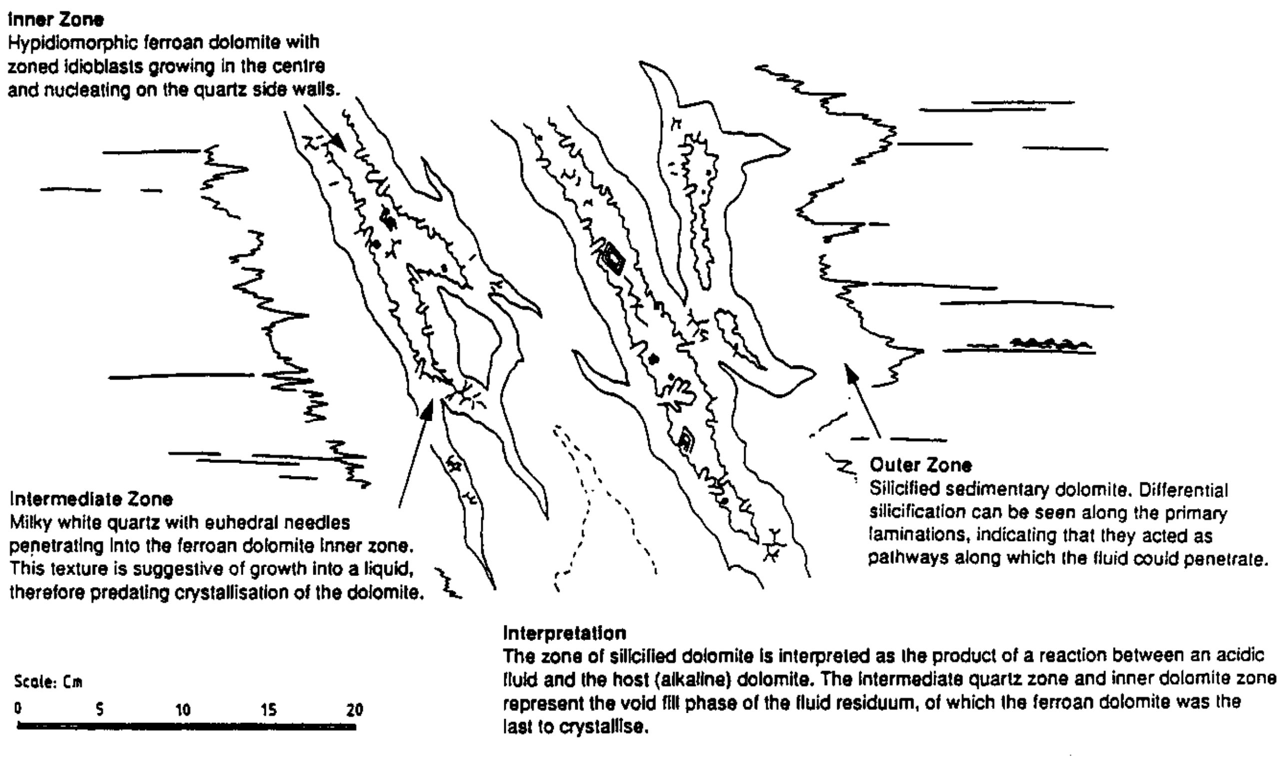


Figure 18. Sketch of ferroan dolomite veining.

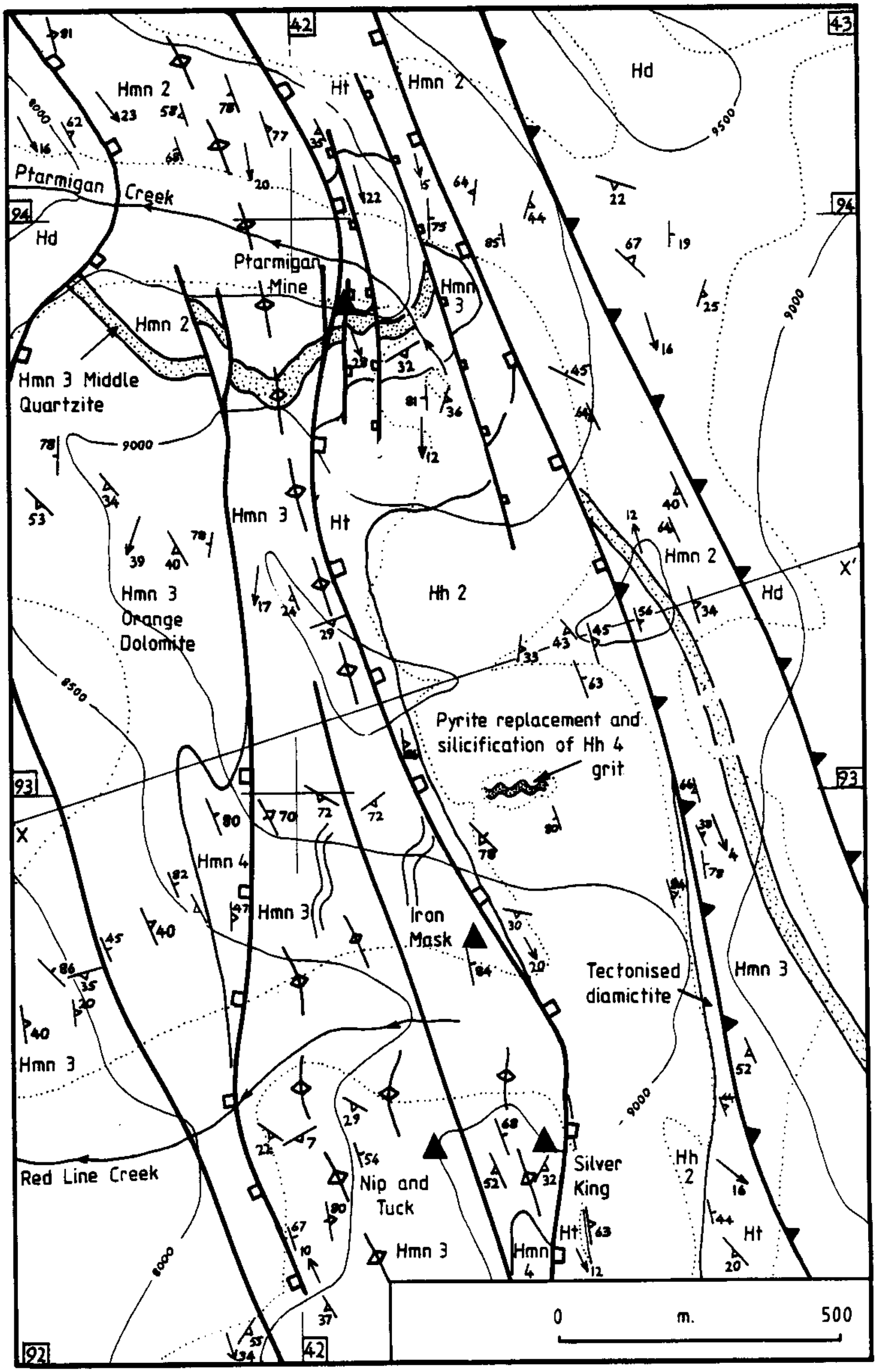


Figure 19a. Geological map of the Ptarmitgan group of mines.
(Symbols and stratigraphic notation as for Figures 29 and 30.)

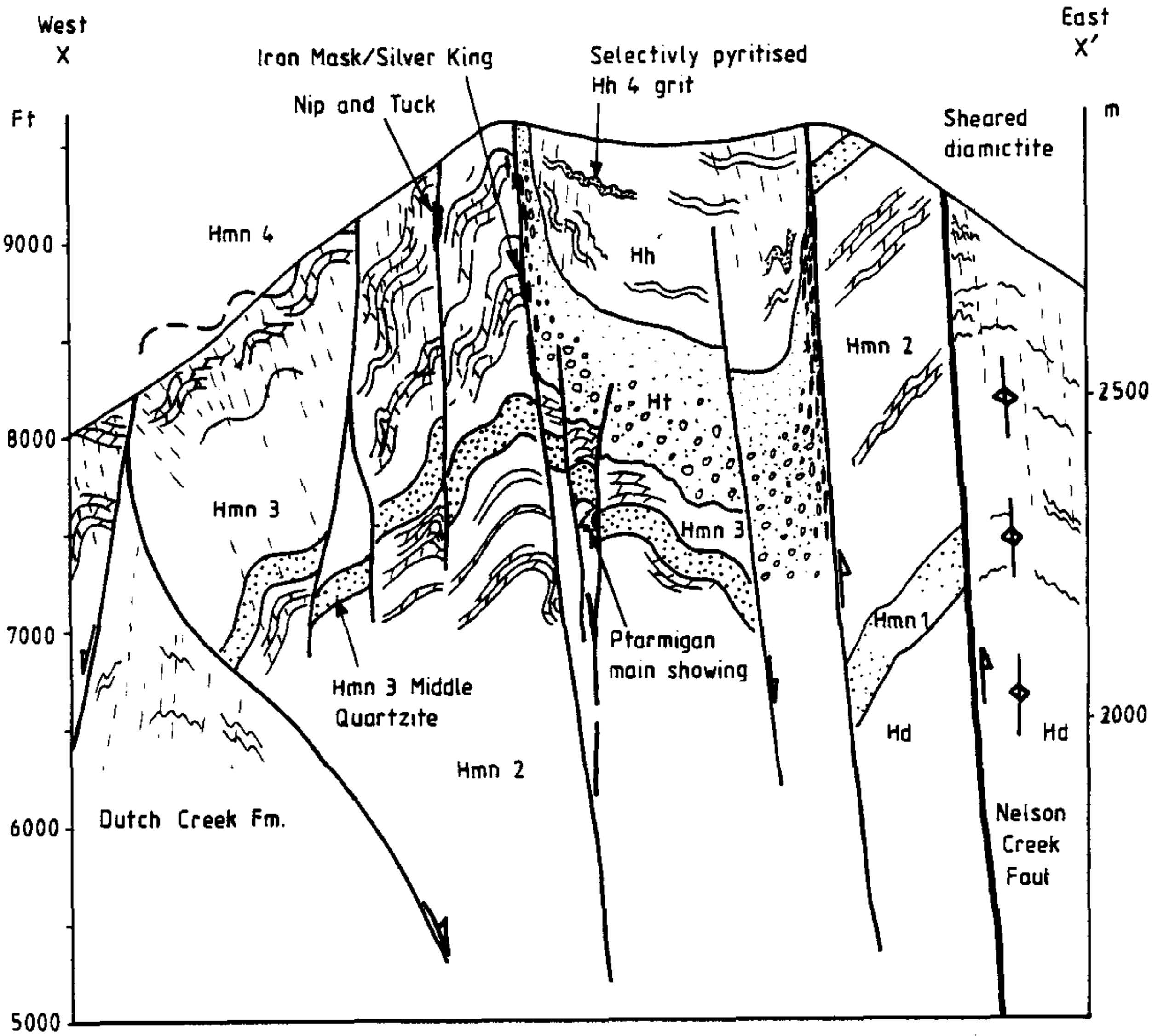


Figure 19b. Geological cross section of the Ptarmigan group of mines.

ure 21). The Windermere unconformity occurs immediately above the Hmn 3 white markers and lower parts of the Hmn 4 Purple sequence, in both the hanging and footwall panels.

The mineralization consists of massive galena with panidiomorphic clumps of tetrahedrite and minor sphalerite, pyrite and chalcopyrite. The tetrahedrite commonly shows alteration to covellite. Freislebenite (diaphorite) and polybasite occur as very small (5 to 10 μm) inclusions in the galena. Another very minor phase in small crosscutting barite-chalcopyrite veins is carrolite. Galena exhibits both curved cleavage-pit traces and bleischweif texture. In addition to the textures at the Delphine mine, a barite-bournonite mylonite with barite porphyroclasts occurs at the aptly named Last Hope-Last Chance prospect near the summit of Mount Catherine (GR 425, 888).

HOT PUNCH MINE

The Hot Punch mine at the head of Delphine Creek (GR 406, 847) at an elevation of 1800 metres is within the immediate footwall of the Hot Punch fault (Figure 22). Very little outcrop is present at the Hot Punch, but Figure 22 shows that it is hosted by the Hmn 3 orange dolomite and possibly the Toby Formation. The ore occurred as a 0.1 to 1 metre wide fissure vein of variable grade in sheared dolomite (MEMPR AR, 1910, 1916; Walker, 1926). A total of approximately 73 tonnes of ore running 1475 grams per tonne silver and 30 per cent lead were shipped (MEMPR AR, 1949). The ore consisted of

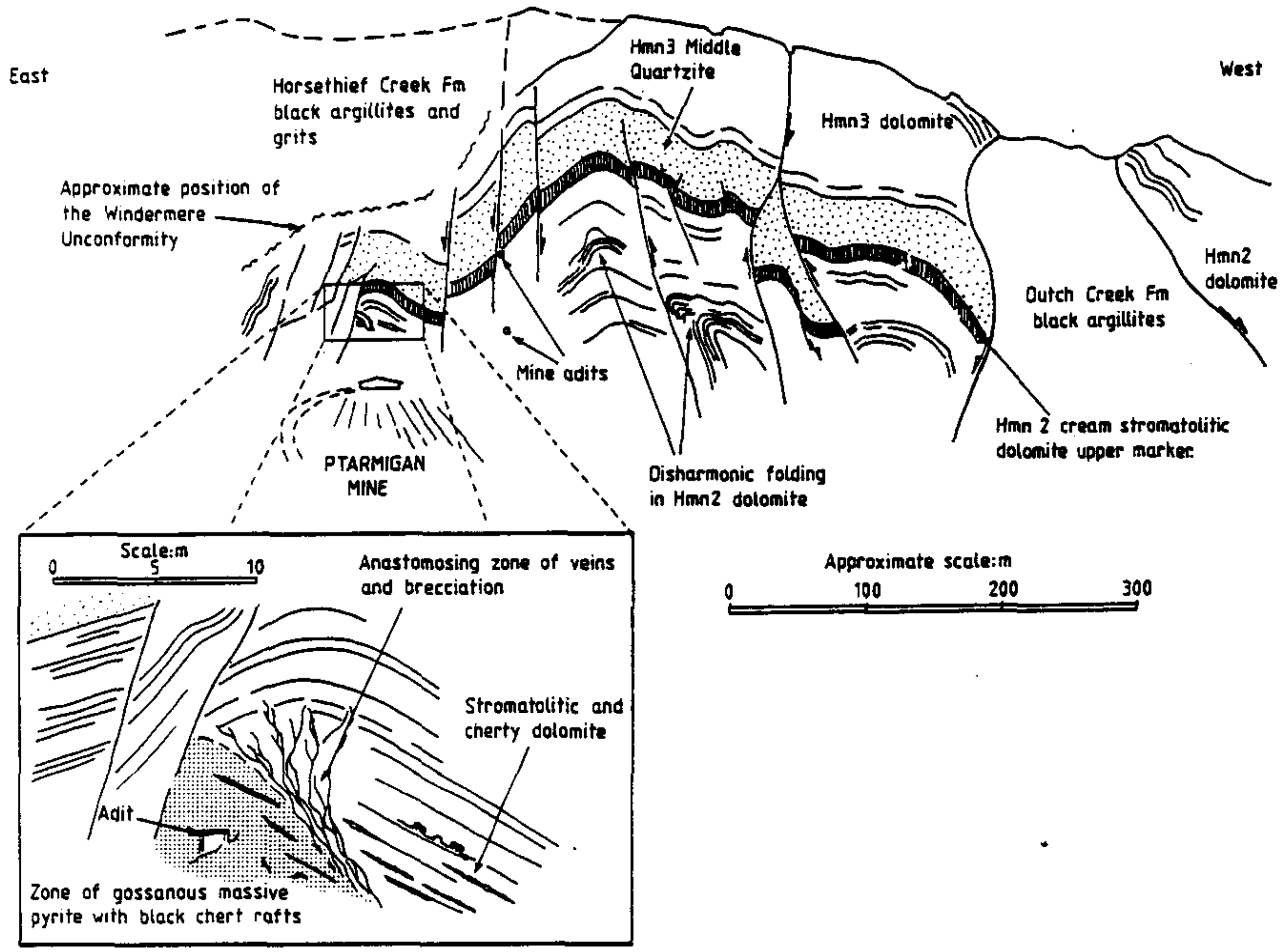


Figure 20. Field sketch of the Ptarmigan mine.

galena and tetrahedrite, with minor chalcopyrite and sphalerite, in quartz and dolomite.

KOOTENAY QUEEN MINE

The Kootenay Queen mine is situated at an elevation of 1980 metres in a small cirque on the south side of Delphine Creek (GR 431, 838). It is hosted in the Hmn 3 white marker sequence and occurs as a steep, bedding-parallel fault vein. The Kootenay Queen mine is immediately below the projected position of the Windermere unconformity, the presence of which is indicated by Toby Formation diamictite on the ridge immediately west of the mine (Figure 23).

The main ore minerals are galena, tetrahedrite and sphalerite; the latter two mainly occurring as inclusions in the galena. Grades of 2400 grams per tonne silver and 70 per cent lead are reported (MEMPR AR, 1901, 1916). The tetrahedrite contains 9 to 10 weight per cent silver and polybasite occurs as very minor inclusions in the galena. Tonnage shipped is not known but it is estimated as less than 45 tonnes from the apparent size of the workings. The ore shows evidence of intense deformation in the form of well developed bleischweif texture and fine-grained polygonal galena indicative of dynamic recrystallization and annealing (McClay, 1980; Craig and Vaughan, 1981).

SILVER QUEEN

The Silver Queen mine is situated at an elevation of 2900 metres at the base of a cliff on the west face of Mount Slade (GR 450, 934) (Figure 24). It comprises a system of small veins hosted by the Hmn 2 dolomite member. The main workings were within a vein about 20 centimetres wide running 2.35 kilograms per tonne silver and 59 per cent lead (MEMPR AR, 1904). The Silver Queen is spatially and genetically (Pope, 1989) associated with a metadiabase dike (Figure 24).

The mineralization comprises galena and sphalerite with minor chalcopyrite and pyrite. The chalcopyrite commonly occurs as an intergrowth parallel to growth twins in the sphalerite which is generally referred to as 'chalcopyrite disease' (Craig and Vaughan, 1981). Pyrite occurs as a separate idiomorphic phase but is commonly seen as hypidiomorphic grains enclosed in massive

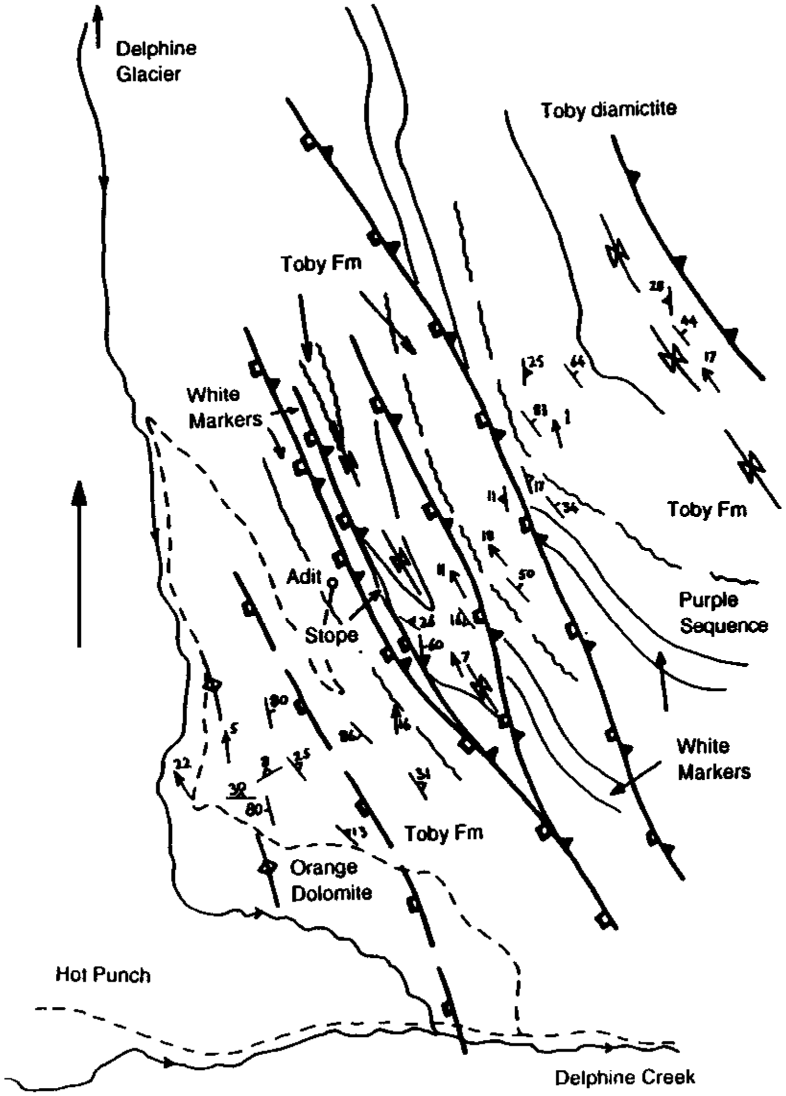


Figure 21. Sketch map of the Delphine mine. [From aerial photograph (BC 7546. n 284)].

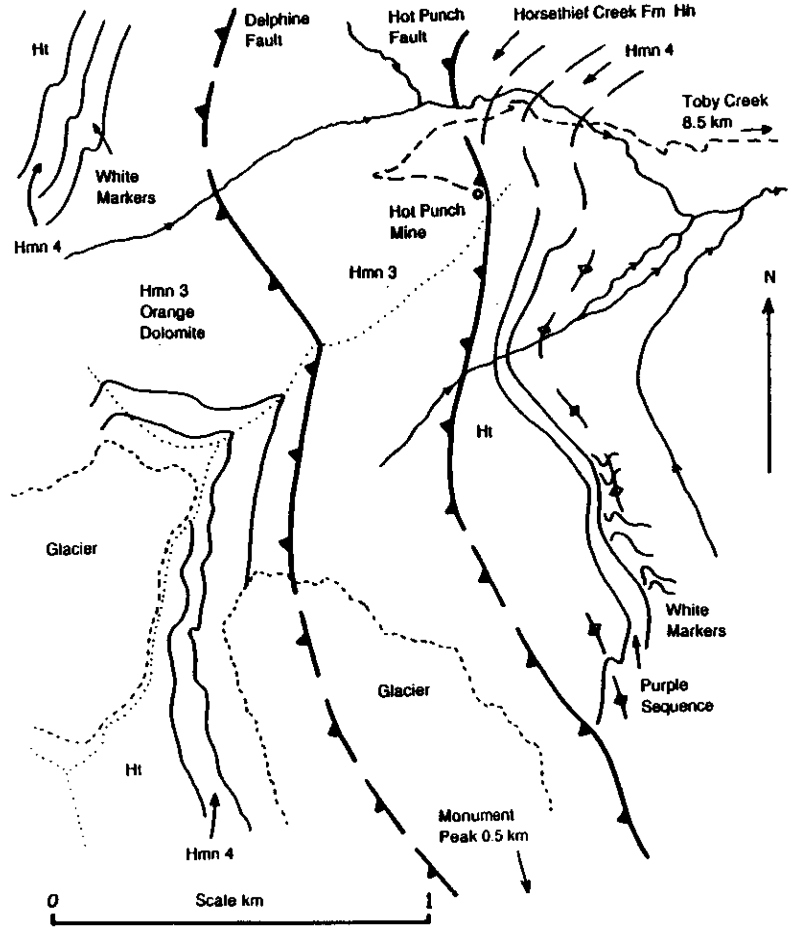


Figure 22. Sketch map of the Hot Punch mine.

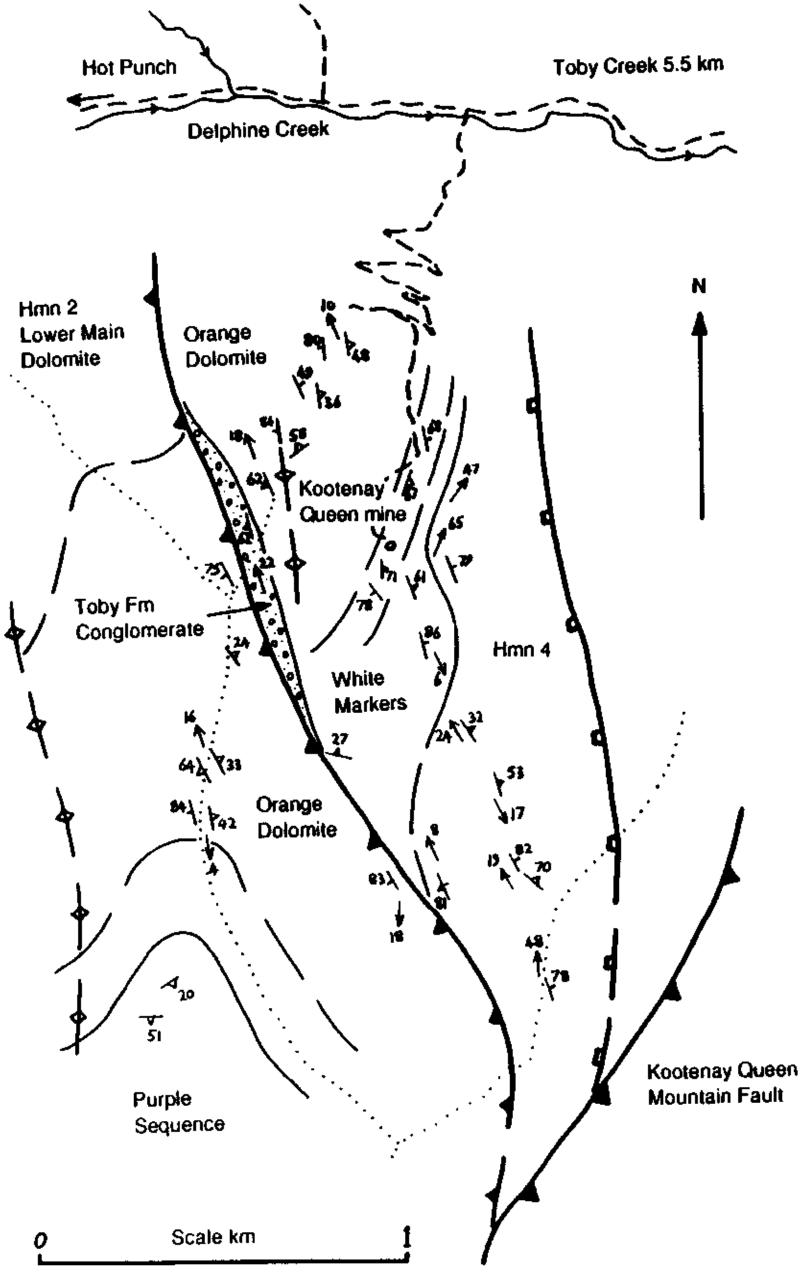


Figure 23. Sketch map of the Kootenay Queen mine.
[From aerial photograph (BC 7546. n 204)].

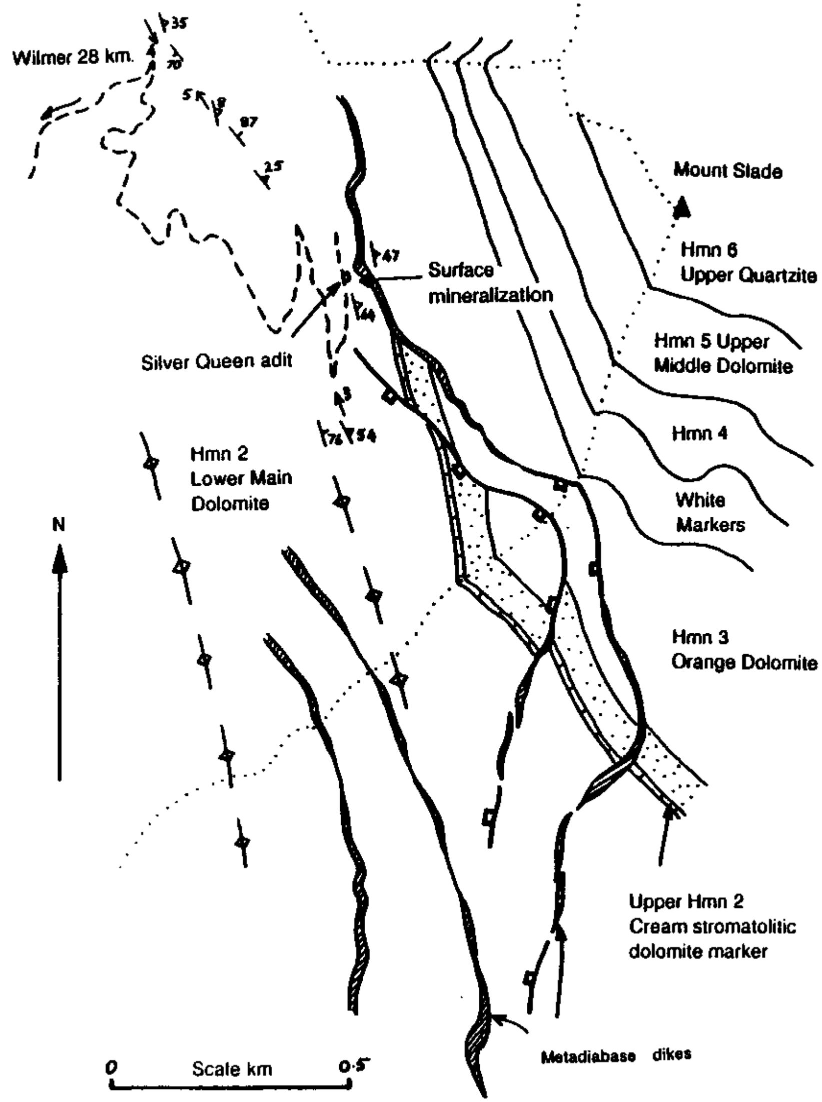


Figure 24. Sketch map of the Silver Queen mine.
[From aerial photograph (BC 7545. n 183)].

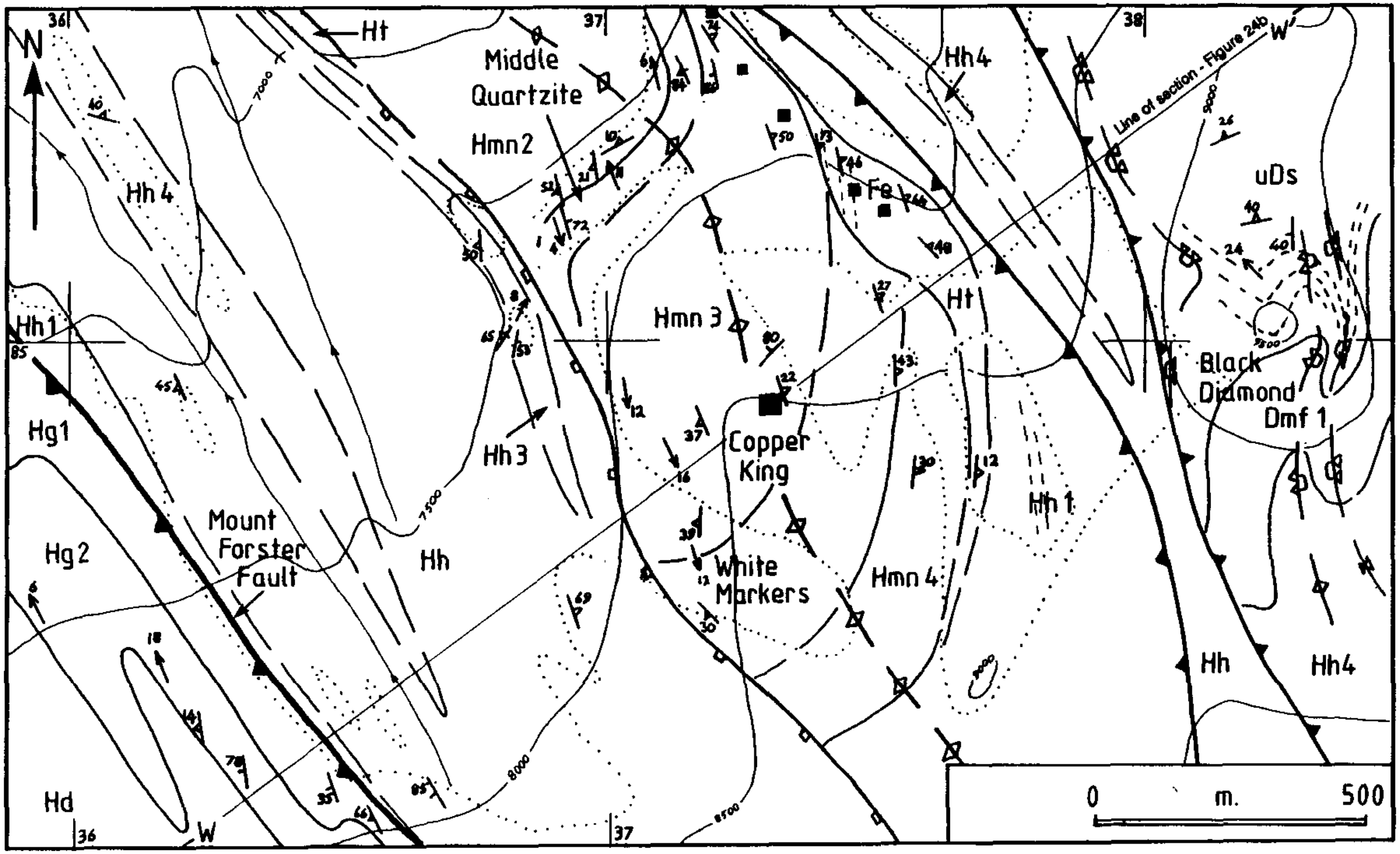


Figure 25a. Geological map of the Copper King mine.

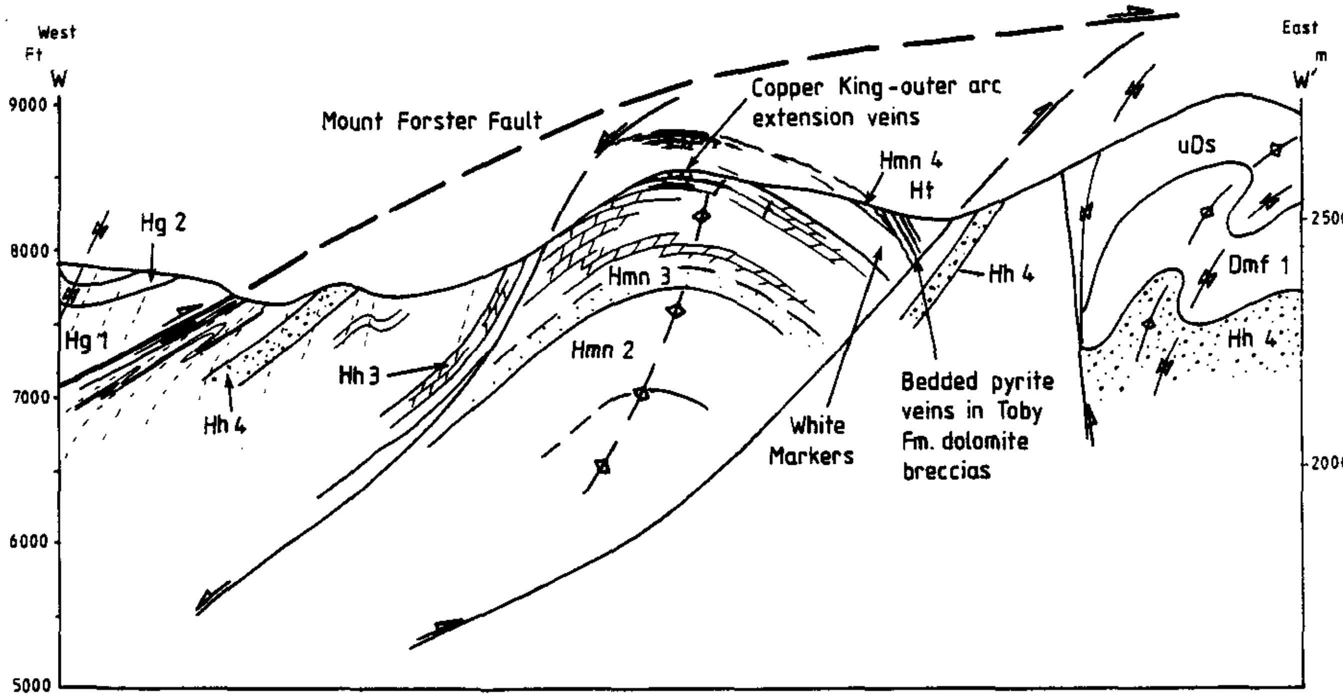


Figure 25b. Geological cross section of the Copper King mine.

sphalerite, suggesting that the sphalerite has recrystallized around the pyrite.

STRATABOUND FRACTURE VEINS (Ag-Pb, Cu-Ba)

These are irregular, bedded and discordant veins of *galena, tetrahedrite, chalcopyrite, bournonite* and boulangerite with subsidiary barite, sphalerite and pyrite. Typically they have very low tonnages (50 tonnes). These deposits are generally confined to dolomites of the Upper Belt-Purcell Supergoup, although there are some minor occurrences in the Hh 3 dolomite, noteably on Paradise ridge at GR 498, 922. The Copper King-Tatler properties in Farnham Creek, the Silver Spray mine in Coppercrown Creek and the Iron King in Law Creek are the main examples. These stratabound fracture veins are commonly fold and unconformity related.

THE COPPER KING MINE

The Copper King mine is within the Tatler group of claims, situated at an elevation of 2230 metres at the southern end of Farnham Creek, near the saddle between Farnham and Black Diamond creeks (GR 373, 847) (Figure 25 and 31). Approximately 20 tonnes of 340 grams per tonne silver and 4.5 per cent copper ore have been shipped (MEMPR AR, 1921).

It is situated in the hinge region of a major north plunging anticline, immediately below the Windermere unconformity (Figure 25). Minor stratabound replacements have formed at nodal points of bedded and discordant fracture vein systems and constitute the largest bodies of ore, for example the Copper King itself. The mineralization consists of bournonite with tetrahedrite, galena, chalcopyrite, covellite and sphalerite. The copper sulphides and sulphosalts are commonly extensively weathered to malachite and azurite.

Mineralization at the Copper King is thought to have formed by ponding of metalliferous fluids below the impermeable Windermere unconformity in fracture systems related to extension of the outer arc of the fold during contractional folding. If this hypothesis is correct, the Copper King deposit must represent the lower part of a vein system that has largely been eroded (schematically illustrated in Figure 25b). The most prospective area would be 600 metres south-southeast of the Copper King mine where the overlying (and in general highly prospective) white marker sequence is preserved in the crest of the anticline below the Windermere unconformity.

SILVER SPRAY

The Silver Spray is part of a group of claims which includes the Lady Bing, Betsy, IOU and Gracie Fraction properties. It is situated at an elevation of 2290 metres on the west side of Coppercrown Creek (GR 458, 750) (Figure 26a). It is contained within the upper Hg 2 dolomite member of the Lower Gateway Formation immediately below the contact with the unconformably overlying Dutch Creek Formation in the crest of an anticline parasitic to the major Coppercrown Anticline (Figure 26b).

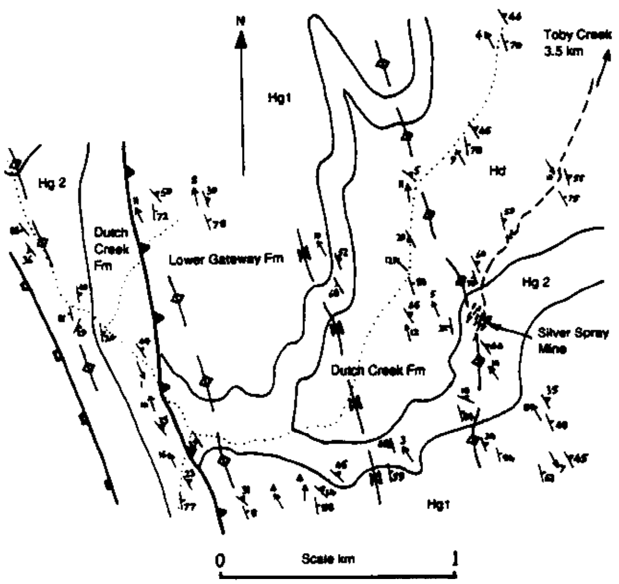


Figure 26a. Sketch map of the Silver Spray mine. [From aerial photograph (BC 7536. n 228)].

The ore consisted of galena, tetrahedrite and cerussite with minor sphalerite and copper carbonates in vertical and bedding-parallel fractures in the order of 5 to 20 centimetres wide (MEMPR AR, 1926; Walker, 1926). This mode of occurrence, coupled with the setting in the crest of a fold, suggests that the mineralization is controlled by fracture systems related to outer arc extension, and that the unconformably overlying Dutch Creek Formation acted as a permeability trap (Figure 26b).

THE IRON KING GROUP

The Iron King is situated on the east slope of Mount Law (GR 452, 958) (Figure 27) at 2300 to 2400-metres elevation. It comprises a number of small veins and pods of pyrite, arsenopyrite and galena, that are hosed in the Hmn 6 upper quartzite and Hmn 5 upper middle dolomite, at the Windermere unconformity. The mineralization appears to occur in fractures and depressions in the pre-Windermere erosion surface of the Mount Nelson Formation, in the footwall of a D_{1b} extension fault (Figure 27).

Pyrite with minor arsenopyrite is limited to the Hmn 6 quartzite, whereas the galena occurs exclusively in the Hmn 5 dolomite. The galena occurs in pods of rubbly ferroan dolomite, described previously as a large showing of siderite (MEMPR AR, 1916), with minor pyrite.

MINOR INDEPENDENT DISCORDANT VEINS

These occurrences are throughout the map area and do not appear to have any structural or stratigraphic controls. They include primary granitic hydrothermal silver-copper-quartz veins and remobilized quartz-dolomite-copper veins.

PRETTY GIRL

The Pretty Girl is situated at an elevation of 2720 metres on the ridge crest between Law and Bruce Creeks (GR 469, 947) and is within argillites of the Horsethief Creek Formation. The mineralization occurred as tetrahedrite and chalcopyrite in a discontinuous quartz vein, with grades of 188 grams per tonne silver, and 27 per cent copper (MEMPR AR, 1904, 1916).

GREEN RIDGE

The Green Ridge prospect is situated in Springs creek at an elevation of 2130 metres (GR 531, 935). It consists of a number of small veins of massive white milky quartz and ferroan dolomite with chalcopyrite, hosted by Hh 4 grits of the Horsethief Creek Formation.

The setting of the Green Ridge mineralization in competent grit units in the immediate footwall of the Panorama-Groto fault (Figure 30 in pocket), may indicate that the mineralization results from pore fluid overpressuring and remobilization during emplacement of the hangingwall Paradise fault panel (Figure 30).

QUARTZ VEINS OF GRANITIC PROVENANCE

Only one vein of this type was identified and it is situated on a saddle between Toby Creek and Dutch Creek (GR 419, 671) (Figure 31). It consists of 1.5 metres of milky quartz with clumps of tetrahedrite and chalcopyrite, and with minor granitic segregations of quartz, orthoclase and K-feldspar. It is hosted in the Lower Gateway Formation Hg 1 member and appears to have formed in a fault dilation zone. The vein occurrence is much closer to the Frying Pan stock and Fry Creek batholith than to the Horsethief Creek batholith. The fact that this is the only observed quartz vein with minor granitic segregations, coupled with its relatively large size, suggests that there may be granite underlying the area of South Toby Creek and the west end of Dutch Creek.

MISSISSIPPI VALLEY TYPE

This type of mineralization consists of lead-zinc cavity filling and replacement in Lower Paleozoic dolomite and dolarenite breccias. The diagnostic field features are internally reworked sediments which appear to have been deposited in karstic cavern systems. The principal examples are the Falcon, Grotto and Whiskey Jack, all of which are hosted in the Lower Cambrian Jubilee Formation. Larger deposits of this type in the Toby-Horsethief Creek region, but external to the map area, include the Baltic, Mitten and Lead Queen (Bennett, 1985).

FALCON PROSPECT

The Falcon property is situated on the southern slope of Mount Forster (GR 477, 036) at an elevation of 1430 metres. The Falcon, Grotto and Whiskey Jack prospects occur on the flat limb of the Mount Forster Syncline in

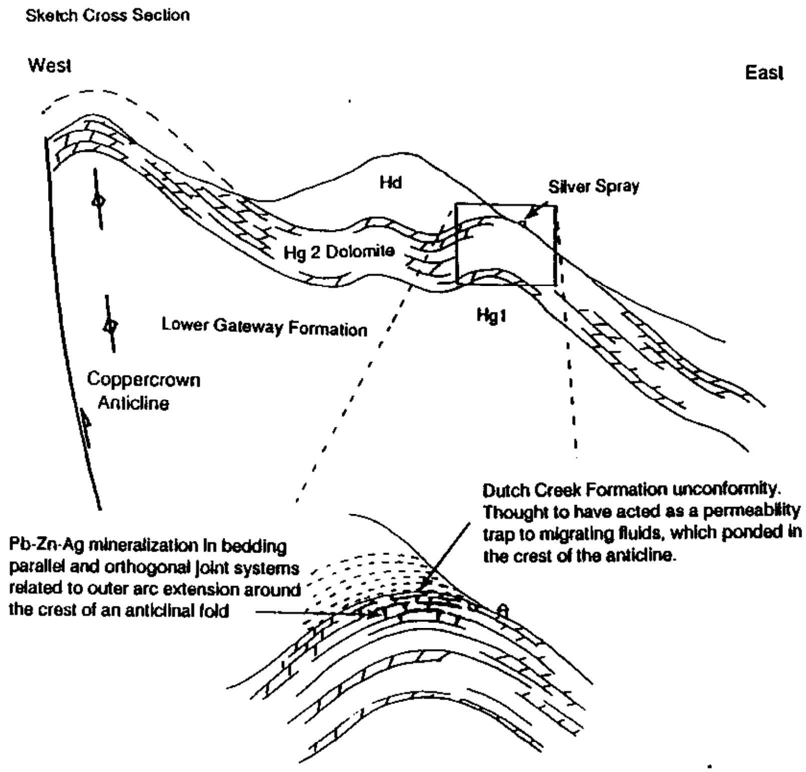


Figure 26b. Cross section of the Silver Spray mine.

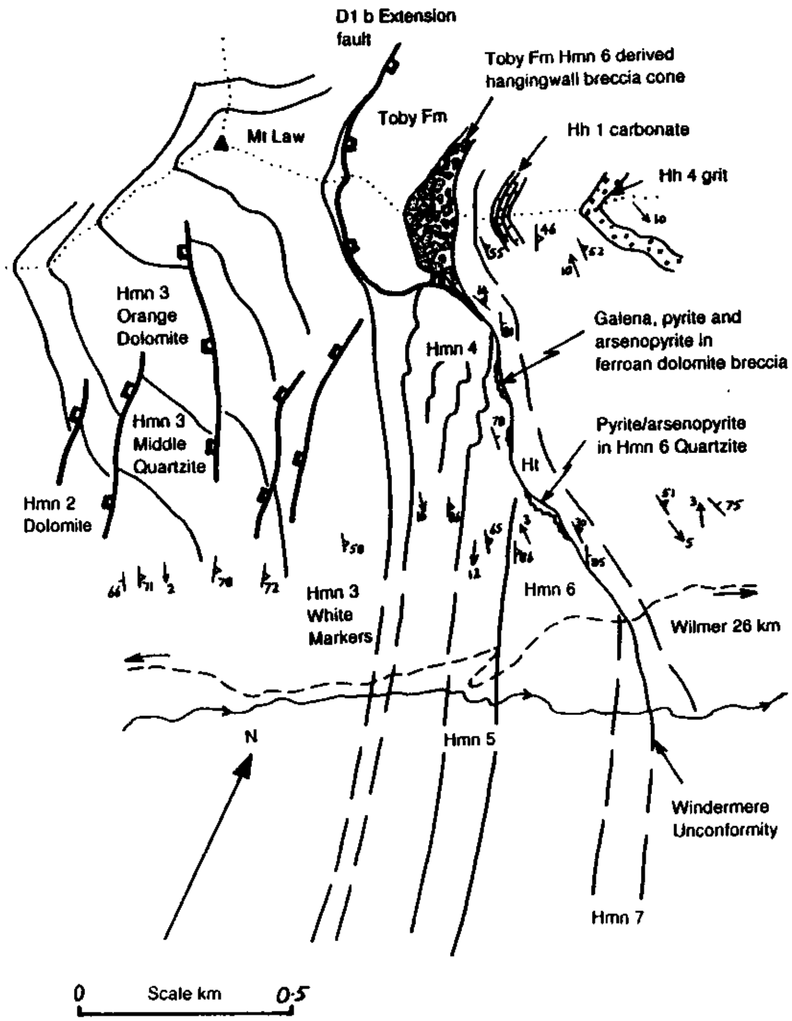


Figure 27. Sketch map of the Iron King Group.
[(From aerial photograph (BC 7545. n 258)].

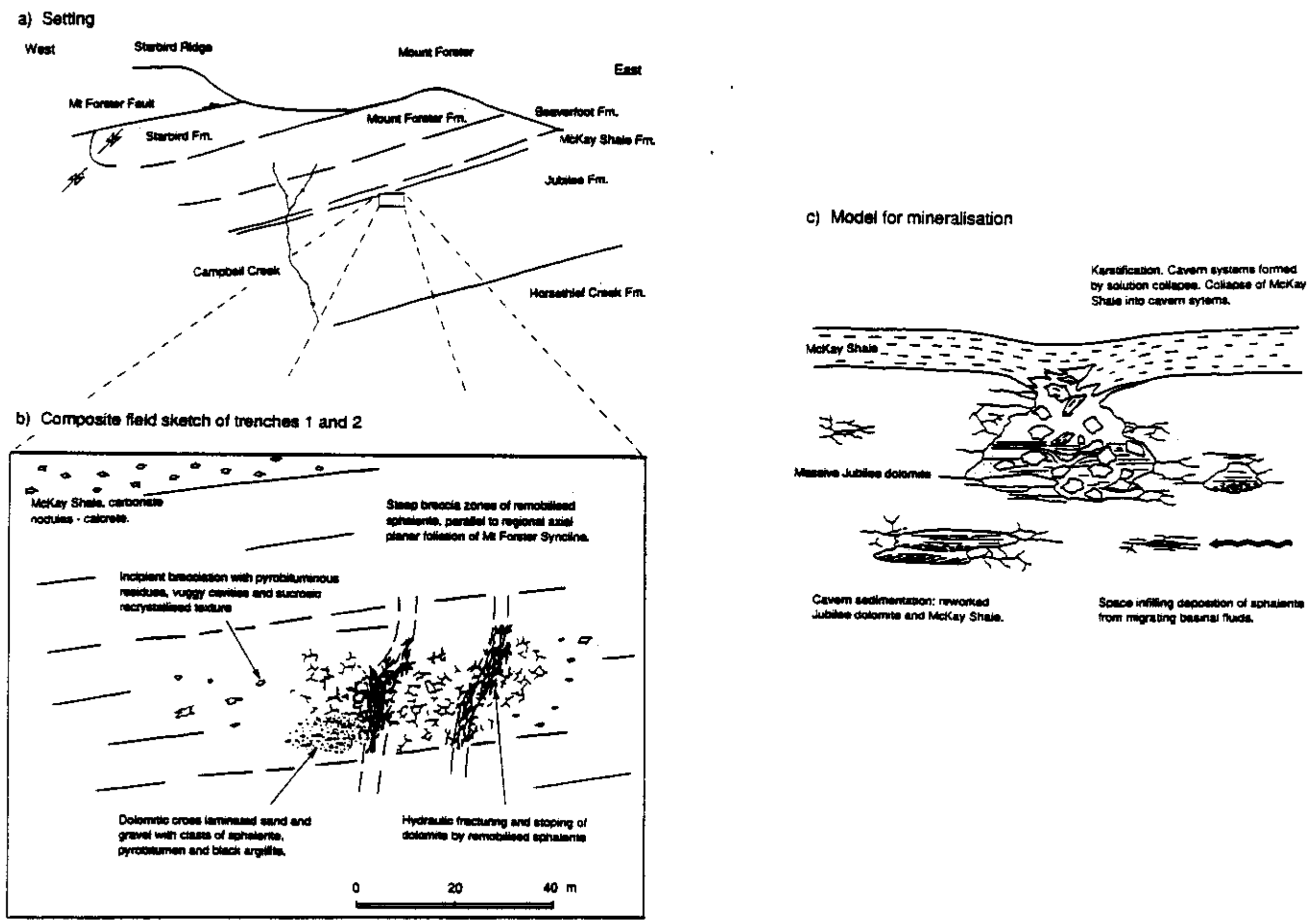


Figure 28. Setting and genesis of the Falcon Prospect. (A) Setting. (B) Composite field sketch of Trenches 1 and 2. (C) Model for mineralization.

the footwall of the Mount Forster fault (Figure 28a). Interpretation of the latter deposits is based on observations made at the Falcon; as they display similar features (A. Louie, personal communication, 1987).

Mineralization observed in trenches on the Falcon property consists almost entirely of sphalerite, but elsewhere on the property galena also occurs. Mineralization and hostrock textures can be divided into primary depositional and secondary deformational.

The Jubilee Formation on the Falcon property is not well bedded but is coarsely crystalline with numerous small vuggy cavities, carbonaceous pressure solution seams and pyrobituminous residues. Bedding-parallel dolarenite sedimentary breccias with clasts of grey to black argillite, dolomite and sphalerite and chips of reworked stylolitic carbonaceous solution seams, occur in the vicinity of the Falcon trenches. These breccias are well bedded and cross laminated indicating current activity, but pass laterally into vuggy, sucrosic, poorly bedded to massive dolomite. A thin sequence of calcretized McKay Formation shales unconformably overlies the Jubilee Formation dolomite.

Trenches one and two are situated within steeply dipping-tectonic breccia vein systems of remobilized sphalerite (Figure 28b). The breccias are sheet like and dip at 80° to 250°, parallel to the axial planar S_1 cleavage of the Mount Forster syncline. Sphalerite forms the matrix and appears to invade and stope dolomite into the breccia. This is suggestive of hydraulic fracturing and is attributed to remobilization of the deposits during folding and formation of the Mount Forster syncline, and emplacement of the overlying Mount Forster thrust sheet.

The breccias are interpreted as sediments deposited in solution collapse cavern systems resulting from karsting. This hypothesis is supported by the presence of black argillite clasts, typical of the unconformably overlying McKay shale, suggesting collapse of the overlying McKay Shale into the Jubilee dolomites followed by underground reworking and deposition in the breccias (Figure 28c).

STRATIFORM DISSEMINATED Zn-Pb±(Ag, Fe)

This type of mineralization consists of low grade disseminated lead-zinc and iron and is confined to the

Middle Devonian Mount Forster Formation. The only known example is the Redmac property in the McDonald Creek drainage.

REDMAC PROSPECT

The Redmac is a stratiform lead-zinc prospect with a strike length in excess of 3 kilometres, situated in Red Line-McDonald Creeks in the immediate footwall of the Mount Forster fault. It is hosted in Middle Devonian Mount Forster Formation Dmf 1 dolomites and sandy dolomites. The mineralized sequence contains calcretes, indicative of groundwater circulation in a subaerial environment (Burley *et al.*, 1985) and thin chloritized mafic tuffs which are thought to correlate with the Devonian volcanics described previously.

Mineralization consists of stratiform disseminated honeyblende sphalerite, galena and pyrite. In the immediate footwall of the Mount Forster fault (within 5 metres of the fault) disseminated pyrite has been remobilized into a tectonic foliation parallel to the fault, which dips at 20° towards 330°. Lower down in the footwall two main showing sequences are less deformed but the disseminated galena, in particular, has undergone recrystallization and remobilization into veinlets.

The reader is referred to Freiholz, (1983) for a comprehensive analysis of the stratigraphic, structural and chemical setting of the mineralization. Mineralization is thought to be related to diagenetic processes involving cation exchange across the groundwater - seawater interface in a tidal flat type environment (Freiholz, 1983).

SUMMARY OF CONTROLS ON MINERALIZATION

INTRODUCTION

Controls on the mineralization may be viewed as stratigraphic, structural and physiochemical. An empirical summary of the controls on mineralization (Table 3) indicates an association between dolomite, the Mount Nelson Formation, the Windermere unconformity and a fault is most likely to produce a mineral occurrence. The specific controls on mineralization are briefly summarized below.

STRATIGRAPHIC CONTROLS

The principal stratigraphic control on the mineralization is the repeated superposition of impermeable units unconformably above dolomitic sequences, providing a barrier to the migration of metalliferous fluids. In each case subtidal to supratidal carbonates (the Lower Gateway Hg 2 member, the Mount Nelson Formation and the Jubilee Formation) are unconformably overlain by deeper water argillitic lithologies (the Dutch Creek Formation, Windermere Supergroup and McKay Shale Group respectively). Conversely, the basal Mount Nelson Formation unconformity places a permeable lithology (the Hmn 1 Lower Quartzite) above an impermeable lithology (Dutch Creek Formation argillites) and is therefore not normally associated with mineralization. The exception to this rule is the Red Hawk barite occurrence in Gopher Creek, which is hosted in the lower Mount Nelson quartzite (A. Louie, personal communication 1987).

DEFORMATIONAL CONTROLS

The role of deformation in controlling the distribution of mineralization is twofold. Mineralization is in most cases spatially controlled by faults and fracture systems, which may have been active or passive, during fluid migration and mineral deposition. The deformation also affected the mineralization by inhomogeneous strain partioning, such that many mineral occurrences were remobilized and concentrated. The best example of the latter process is the Mineral King mine in which the ore has been concentrated, by limb to hinge mass transfer, from a generally tabular body into a series of interconnected cylindical bodies in fold hinge zones (Fyles, 1960; Pope, 1989). This can be clearly observed from hand specimen to the deposit scale. Another good example of strain partitioning is the Falcon Property, where disseminated clasts of sphalerite have been reworked into massive vein breccia systems parallel to the regional foliation. This latter process could have been critical in determining whether some mineral occurrences achieved ore grade.

PHYSICOCHEMICAL CONTROLS

The principal physicochemical control, for all replacement style mineral occurrences is a dolomite host rock. Dolomites are alkaline and their preferential mineralization indicates that mineralizing fluid(s) had a lower pH. It has been demonstrated by Pope (1989) that fluids probably leached lead and barium from alkali feldspar in the Horsethief Creek grits, a process that would require the fluid to be acidic (Barnes and Czamanske, 1967; Badham, 1981).

METALLOGENESIS OF THE TOBY-HORSETHIEF CREEK AREA

INTRODUCTION

Mineral deposits of the Toby-Horsethief Creek area can be subdivided into passive margin (Type 1) and collisional (Type 2) settings; (*see* summary of ore textures and mineral parageneses, Table 4) as can be broadly shown for the Canadian Cordillera as a whole (McMillan *et al.*, 1987). Through detailed mapping of the regional structure and stratigraphy it is possible to tie this mineralization into a precise template of structure and stratigraphy relating to the Windermere high, both before and after the Mesozoic contraction. A two-stage model for the metallogenesis of the northeast flank of the Purcell anticlinorium has been developed and is discussed below:

TYPE 1 MINERALIZATION

Type 1 Mineralization is considered in terms of basin dewatering resulting from the superposition of sedimentary basins, during at least four protracted phases of synsedimentary faulting (Pope, 1989), as can be shown for the ancestral Cordilleran margin as a whole (Thompson *et al.*, 1987). Mechanisms of fluid migration, source of basemetals and precipitating agents are discussed below with reference to the Toby-Horsethief Creek area and the structure of the Windermere high.

Basin dewatering in a rift environment (as opposed to a sag basin) lends itself to the mineralizing process in that fluid is retained and then expelled in large volumes in an episodic process, rather than draining away at a slow but constant rate. Another key aspect of a rift environment is that it is characterized by high heat flow (Lucazeau and Le Douaran, 1985; Robinson, 1987). This results in the generation of large volumes of fluid by dehydration reactions (Burley *et al.*, 1985; Robinson, 1987) whilst enhancing the leaching potential of the fluids (Badham, 1981; Vogt and Stumpfl, 1987) and not least, expelling them to the surface.

A likely mechanism of fluid expulsion in a rift environment is seismic pumping, postulated by Sibson *et al.* (1975). The attraction of seismic pumping as a mechanism is that it focuses a basinal fluid (during shear-stress dilation of a fault zone prior to brittle failure), before expelling the fluid as a concentrated pulse, of sufficient volume to swamp any kinetic buffers to metal precipitation in the trap environment.

SOURCE OF METALS

It has been shown by Pope (1989) that alkali feldspars in the Horsethief creek grits are depleted in barium, indicating that the grits may have been one of the major sources for metals during basin dewatering. In the literature alkali feldspars in arkosic grits are frequently postulated as a source of lead and barium. Goodfellow and Jonasson (1983) proposed arkosic grits of the Windermere Supergroup as the source of lead and barium in the Selwyn basin of the northern Canadian Cordillera. Furthermore, arkosic grits are proposed as the source of lead-zinc for Mississippi Valley-type mineralization at Pine Point (Bjorlykke and Sangster, 1981) and in southeast Missouri (Leach, 1980), and for stratabound mineralization in the Bangemall Basin, Australia, by Vogt and Stumpfl (1987).

SOURCE OF PRECIPITANTS

Within the stratigraphy of the Windermere high, evaporite bearing sequences abound in the Upper Belt-Purcell Supergroup and are common in Lower and Upper Paleozoic sequences. Thus a source of sulphur, a prerequisite for metal precipitation (Dunsmore and Shearman, 1977; Badham, 1981; Kyle, 1981; Clemmey, 1985; Edwards and Atkinson, 1986) would have been readily available for both the syngenetic and epigenetic menu of traps offered by the Windermere high. Bennett (1985), reported the ubiquitous occurrence of evaporite and cryptalgal-laminated horizons in the Lower Paleozoic Jubilee Formation, which is host to all of the Mississippi Valley-type deposits.

The relative abundance of mineralization even for Mesozoic-Tertiary veins in the originally more evaporitic Hg 2, Hmn 3 and Hmn 7 dolomites as opposed to the Hmn 2 and Hmn 5 dolomites, strongly suggests the presence of a significant amount of primary sulphates right through until the Tertiary.

ENVIRONMENTS OF MINERAL DEPOSITION

A fluid migrating up the faults around the Windemere high would have frequently encountered the 'trap combination' of a fault, permeability barrier (Windermere Supergroup, Dutch Creek Formation and McKay Group) and sulphate-bearing dolomite hostrock.

Mississippi Valley-type mineralization is confined to the Cambrian Jubilee Formation dolomite which is strongly recrystallized and has a high secondary porosity, suggesting that it originated as a limestone (as would be expected in the Phanerozoic; Tucker, 1982). Dolomitization of limestone is a characteristic feature of Mississippi Valley-type mineralization, for example, the Pres'que Isle facies in the Pine Point district (Rhodes *et al.*, 1984).

Contemporaneous (and cogenetic) epigenetic mineralization in the underlying dolomites of the Belt-Purcell Supergroup would tend to form manto deposits. The only difference between the Mississippi Valley-type and manto-type occurrences is that egress of fluids into the Belt-Purcell dolomites would have been retarded by lack of porosity, to the extent that the fluids had to volumetrically replace the dolomite rather than fill spaces. The lack of porosity reflects a), the absence of Precambrian framework organisms necessary to bestow a primary porosity and b), the primary origin of Precambrian dolomites (Badham, 1981).

Fluids that escaped into the syngenetic environment are thought to have precipitated in the diagenetic vadose zone of a semi-arid fluvial to tidal-flat environment; this is indicated by the presence of calcretes and interbedding of red (subaerial-oxidizing) and green (subaqueous-reducing) unit, in the Mount Forster Formation.

TIMING OF MINERALIZATION

Syngenetic sulphides in the Mount Forster Formation at the Redmac deposit, indicate that mineralization occurred during the Middle Devonian (Eifelian). In addition, lead isotope work by Bennett (1985) suggests a Devonian date for some examples of mineralization north of the Toby-Horsethief Creek area. The Devonian is an upper age limit on basin dewatering mineralization but does not preclude the possibility of mineralization during the Lower Paleozoic, Hadrynian, or the Helikian which hosts the Sullivan massive lead-zinc deposit. Episodic basin dewatering by its nature would repeatedly inundate the same traps with metalliferous fluid, overprinting earlier mineralization.

However, a Middle to Late Devonian age for basin dewatering mineralization around the margins of the Windermere High is the most likely due to:

(a) the regional occurrence of sedimentary and volcanogenic exhalative mineralization at this time (Eisbacher, 1983; McClay *et al.*, 1987);

(b) the Mid to Late Devonian is widely regarded to be the time of final continental separation and rifting of the passive margin (Struik, 1988; Thompson *et al.*, 1987); and as such would be characterized by high heat flow and basin dewatering (Lucazeau and Le Douaran, 1985).

Episodic brine expulsion over a short time period in the Middle to late Devonian could have contemporaneously produced sedex/diagenetic deposits in half-graben basins around the margins and crest of the Windermere High (*i.e.* Redmac); epigenetic Mississippi Valley type deposits in Cambrian limestones, which would have had little more than 100-200 metres of Ordovician to Lower Middle Devonian sediment above them (Reesor, 1973) and at deeper levels, epigenetic manto replacement of Belt Purcell dolomites.

TYPE 2 MINERALIZATION

Most of the mineralization in the Toby-Horsethief Creek area is deformed to a certain extent. Remobilization of stratiform lead-zinc-silver (Type 1 mineralization) into discordant vein deposits associated with Late-Cretaceous uplift (Type 2 mineralization) has been recognized in the Kootenay Arc by Linnen and Williams-Jones (1987). In addition to remobilization there is convincing evidence of a primary input associated with both quartz-monzonitic plutonism and deformation/prograde metamorphism. There are two main lines of evidence for this:

(1) The abundance of silver in the vein deposits (Table 4). Buddington (1927) noted a silver-lead association with quartz monzonite granites in the Canadian Cordillera (as compared to gold-zinc with quartz diorites, and gold-copper-iron with diorites), thus establishing a generally accepted genetic link (*e.g.* Andrews, 1986; Godwin *et al.*, 1986) between silver mineralization and Middle to Late Cretaceous quartz monzonite plutonism in British Columbia. Silver similarly to copper can also be attributed to Type 2 mineralization by process of elimination, due to its normally very low concentration in Mississippi Valley-type solutions (Edwards and Atkinson, 1986).

(2) The temperature (250° to 350° C) and composition (8 equivalent weight per cent NaCl and 25 weight per cent CO_2 with 14 mole per cent CH_4) of the ore-forming fluid determined from quartz intimately associated with the mineralization (Pope, 1989), indicates a metamorphic origin (Hollister, 1981; Roedder, 1981, 1984).

Type 2 mineralization occurred in the same range of structural and stratigraphic traps as the Type 1, indicating continued influence by the Windermere high, even after incorporation into the Cordilleran fold and thrust belt. It is not clear to what extent the abundance of high grade silver-lead-copper fault and fracture veins in the Hmn 3 white marker sequence (*e.g.* Delphine Group; Hot Punch; Kootenay Queen) reflects the continued presence of sulphate ions in the evaporitic horizons; since these occurrences are also directly controlled by the proximity of the Windermere unconformity. It is however possible that sulphate was present to act as a precipitant in the wallrocks during the Late Mesozoic-Tertiary Type 2 mineralization.

REFERENCES

Andrews, A.J. (1986): Silver Vein Deposits: Summary of Recent Research; *Canadian Journal of Earth Sciences*, 23, pages 1459-1462.

Atkinson, S.J. (1975): Surface Geology of the Paradise Basin; *in* Geology in British Columbia; *B.C. Ministry of Energy, Mines and Petroleum Resources*, pages 7-12.

Badham, J.P.N. (1981): Ore Deposits in Sediments; *in* Economic Geology and Geotectonics, Tarling, D.H., Editor; *Blackwell Scientific Publications*.

Barnes, H.L. and Czamanske, G.K. (1967): Solubilities and Transport of Ore Metals; *in* Geochemistry of Hydrothermal Ore Deposits; *Barnes, H.L.*, 1967.

Bennett, S.M.H. (1985): Tectonics, Sedimentation and Mineralization on the East Flank of the Purcell Anticlinorium, Southeast British Columbia, Canada; unpublished Ph.D. thesis; *University of London*, England.

Bjorlykke, A. and Sangster, D.F. (1981): An Overview of Sandstone-lead Deposits and Their Relation to Red-bed Copper and Carbonate Hosted Lead-Zinc Deposits; *Economic Geology*, 75 Anniversary Volume, pages 179-213.

Buddington, A.F. (1927): Coincident Variations of Types of Mineralization and of Coast Range Intrusives; *Economic Geology*, 22, pages 158-179.

Burley, S.D., Kantorowicz, J.D. and Waugh, B. (1985): Clastic Diagenesis; *in* Sedimentology, Recent Developments and Applied Aspects, P.J. Brenchley and B.P.J. Williams, Editors, *Geological Society of London*, Special Publication, Number 17, pages 189-226.

Butler, R.W.H. (1982): The Terminology of Structures in Thrust Belts; *Journal of Structural Geology*, Volume 4, Number 3, pages 239-245.

Clemmey, H. (1985): Sedimenary Ore Deposits; *in* Sedimentology, Recent Developments and Applied Aspects; P.J. Brenchley and B.P.J. Williams, Editors; *Geological Society of London*, Special Publication Number 17, pages 229-247.

Cook, F.A., Simony, P.S., Coflin, K.C., Green, A.G., Milkereit, B., Price, R.A., Parrish, R., Patenaude, C., Gordy, P.L. and Brown, R.L. (1987): Lithoprobe Southern Canadian Transect: Rocky Mountain Thrust Belt to Valhalla Gneiss Complex; *Geophysical Journal of the Royal Astonomical Society*, Volume 89, pages 91-98.

Cooper, M.A. and Trayner, P.M. (1986): Thrust-surface Geometry: Implications for Thrust-belt Evolution and Section Balancing Techniques; *Journal of Structural Geology*, Volume 8, Numbers 3 and 4, pages 305-312.

Craig, J.R. and Vaughan, D.J. (1981): Ore Microscopy and Ore Petrography; *John Wiley and Sons*.

Dahlstrom, C.D.A. (1970): Structural Geology in the Eastern Margin of the Canadian Rocky Mountains; *Canadian Petroleum Geology Bulletin*, Volume 18, Number 3, pages 332-406.

Dunsmore, H.E. and Shearman, D.J. (1977): Mississippi Valley-type Lead-Zinc Orebodies: A Sedimentary and Diagenetic Origin; *in* Forum on Oil and Ore in Sediments, P. Garrard, Editor; *Imperial College London*, pages 189-202.

Edwards, R. and Atkinson, K. (1986): Ore Deposit Geology and Its Influence on Exploration; *Chapman and Hall*, London, New York.

Eisbacher, G.H. (1983): Devonian-Mississippian Sinistral Tranccurrent Faulting Along the Cratonic Margin of Western North America: A hypothesis; *Geology*, Volume 11, pages 7-10.

Foley, S.F.G., Venturelli, G., Green, D.H., and Toscani, L. (1987): The Ultrapotassic Rocks: Characteristics, Classification and Constraints for Petrogenetic Models; *Earth Science Reviews*, Volume 24, pages 81-134.

Foo, W.K. (1979): Evolution of Transverse Structures Linking the Purcell Anticlinorium to the Western Rocky Mountains Near Canal Flats, British Columbia; unpublished M.Sc. thesis; *Queens University*, Kingston, Ontario.

Freiholz, G. (1983): The Stratigraphic and Structural Setting of a Lead-Zinc Occurrence Near Invermere, Southeast British Columbia; unpublished M.Sc. thesis; *University of Calgary*.

Fyles, J.T. (1960): Mineral King (Sheep Creek Mines Ltd.); *B.C. Ministry of Energy, Mines and Petroleum Resources*, British Columbia Annual Report 1959, pages 74-89.

Godwin, C.I., Watson, P.H. and Kun Shen (1986): Genesis of the Lass Vein System, Beaverdell Silver Camp, South-central British Columbia; *Canadian Journal of Earth Sciences*, 23, pages 1615-1626.

Goodfellow, W.D. and Jonasson, I.R. (1983): Environment of Formation of the Howards Pass (XY)

Deposit, Selwyn Basin, Yukon; *in* Mineral Deposits of the Northern Cordillera; *Canadian Institute of Mining and Metallurgy*, Special Volume 37, Morin, J.A., Editor.

Hollister, L.S. (1981): Information Intrinsically Available From Fluid Inclusions; *Mineralogical Association of Canada*, Short Course in Fluid Inclusions; Applications to Petrology, L.S. Hollister and M.L. Crawford, Editors.

Höy, T. and Van der Heyden, P. (1988): Geochemistry, Geochronology and Tectonic Implications of Two Quartz Monzonite Intrusions, Purcell Mountains, Southeastern British Columbia; *Canadian Journal of Earth Sciences*, Volume 25, pages 106-115.

Kyle, J.R. (1981): Geology of the Pine Point Lead-zinc District; *in* Handbook of Stratabound and Stratiform Ore Deposits, Volume 9, pages 643-741, K.H. Wolf, Editor; *Elsevier*, New York.

Le Maitre, R.W. (1989): A Classification of Igneous Rocks and Glossary of Terms; Recommendations of the International Union of Geological Sciences Subcommission on the Systematics of Igneous Rocks; *Blackwell Scientific Publications*.

Leach, D.L. (1980): Nature of Mineralizing Fluids in the Barite Deposits of Central and Southeast Missouri; *Economic Geology*, Volume 75, pages 1168-1180.

Linnen, R.L. and Williams-Jones, A.E. (1987): Tectonic Control of Quartz Vein Orientations at the Trout Lake Stockwork Molybdenum Deposit, Southeastern British Columbia: Implications for Metallogeny in the Kootenay Arc; *Economic Geology*, Volume 82, pages 1283-1293.

Lucazeau, F. and Le Douaran, S. (1985): The Blanketing Effect of Sediments in Basins Formed by Extension: A Numerical Model; Application to the Gulf of Lion and Viking Graben; *Earth and Planetary Science Letters*, Volume 74, pages 92-102.

McClay, K.R. (1980): Sheared Galena; Textures and Microstructures; *Journal of Structural Geology*, Volume 2, Number 1/2, pages 227-234.

McClay, K.R., Insley, M.W., Way, N.A. and Anderton, R. (1987): Tectonics and Mineralization of the Kechika Trough, Gataga Area, Northeastern British Columbia; *in* Current Research, Part A; *Geological Survey of Canada*, Paper 87-1A.

McMillan, W.J., Panteleyev, A. and Höy, T. (1987): Mineral Deposits in British Columbia: A Review of Their Tectonic Settings; *in* GeoExpo/86: Exploration in the North American Cordillera, I.L. Elliott and B.W. Smee, Editors; *Association of Exploration Geochemists*.

Morley, C.K. (1988): Out of Sequence Thrusts; *Tectonics*, Volume 7, Number 3, pages 539-561.

Norford, B.S. (1981): Devonian Stratigraphy at the Margins of the Rocky Mountain Trench, Columbia River, Southeastern British Columbia; *Bulletin Canadian Petroleum Geology*, Volume 29, Number 4, pages 540-560.

Pell, J. and Simony, P.S. (1987): New Correlations of Hadrynian Strata, South-central British Columbia; *Canadian Journal of Earth Sciences*, Volume 24, pages 302-313.

Pope, A.J. (1989): The Tectonics and Mineralization of the Toby-Horsethief Creek Area, Purcell Mountains, Southeast British Columbia, Canada; unpublished Ph.D. thesis; *University of London*, England.

Price, R.A. (1981): The Cordilleran Foreland Thrust and Fold Belt in the Southern Canadian Rocky Mountains; *in* Thrust and Nappe Tectonics; McClay, K.R. and Price, N.J., Editors; *Geological Society of London*, Special Publication Number 9.

Reesor, J.E. (1973): Geology of the Lardeau Map-Area, East-Half, British Columbia; *Geological Survey of Canada*, Memoir 369.

Rich, J.L. (1934): Mechanics of Low-angle Overthrust Faulting as Illustrated by Cumberland Thrust Block, Virginia, Kentucky, and Tennessee; *American Association of Petroleum Geologists*, Bulletin Volume 18, pages 1584-1587.

Roedder, E. (1981): Origin of Fluid Inclusions and Changes That Occur After Trapping; *Mineralogical Association of Canada*, Short Course in Fluid Inclusions; Applications to Petrology, L.S. Hollister and M.L. Crawford, Editors.

Roedder, E. (1984): Fluid Inclusions. Reviews in Mineralogy Volume 12; *Mineral Society of America*, Series, P.H. Ribbe, Editor.

Rhodes, D., Lanthos, E.A., Lanthos, J.A., Webb, R.J. and Owens, D.C. (1984): Pine Point Orebodies and Their Relationship to the Stratigraphy, Structure, Dolomitization and Karstification of the Middle Devonian Barrier Complex; *Economic Geology*, Volume 79, pages 991-1055.

Robinson, D. (1987): Transition from Diagenesis to Metamorphism in Extensional and Collision Settings; *Geology*, Volume 15, pages 866-869.

Root, K.G. (1983): Upper Proterozoic and Paleozoic Stratigraphy, Delphine Creek Area, Southeastern British Columbia; Implications for the Purcell Arch; *in* Current Research, Part B; *Geological Survey of Canada*, Paper 83-1B, pages 377-380.

Root, K.G. (1985): Reinterpretation of the Age of a Succession of Paleozoic Strata, Delphine Creek, Southeastern British Columbia; *in* Current Research, Part A; *Geological Survey of Canada*, Paper 85-1A, pages 727-730.

Sibson, R.H., Moore, J.McM. and Rankin, A.H. (1975): Seismic Pumping - A Hydrothermal Fluid Transport

Mechanism; *Journal Geological Society of London*, Volume 131, pages 653-659.

Struik, L.C. (1988): Crustal Evolution of the Eastern Canadian Cordillera; *Tectonics*, Volume 7, Number 4, pages 727-747.

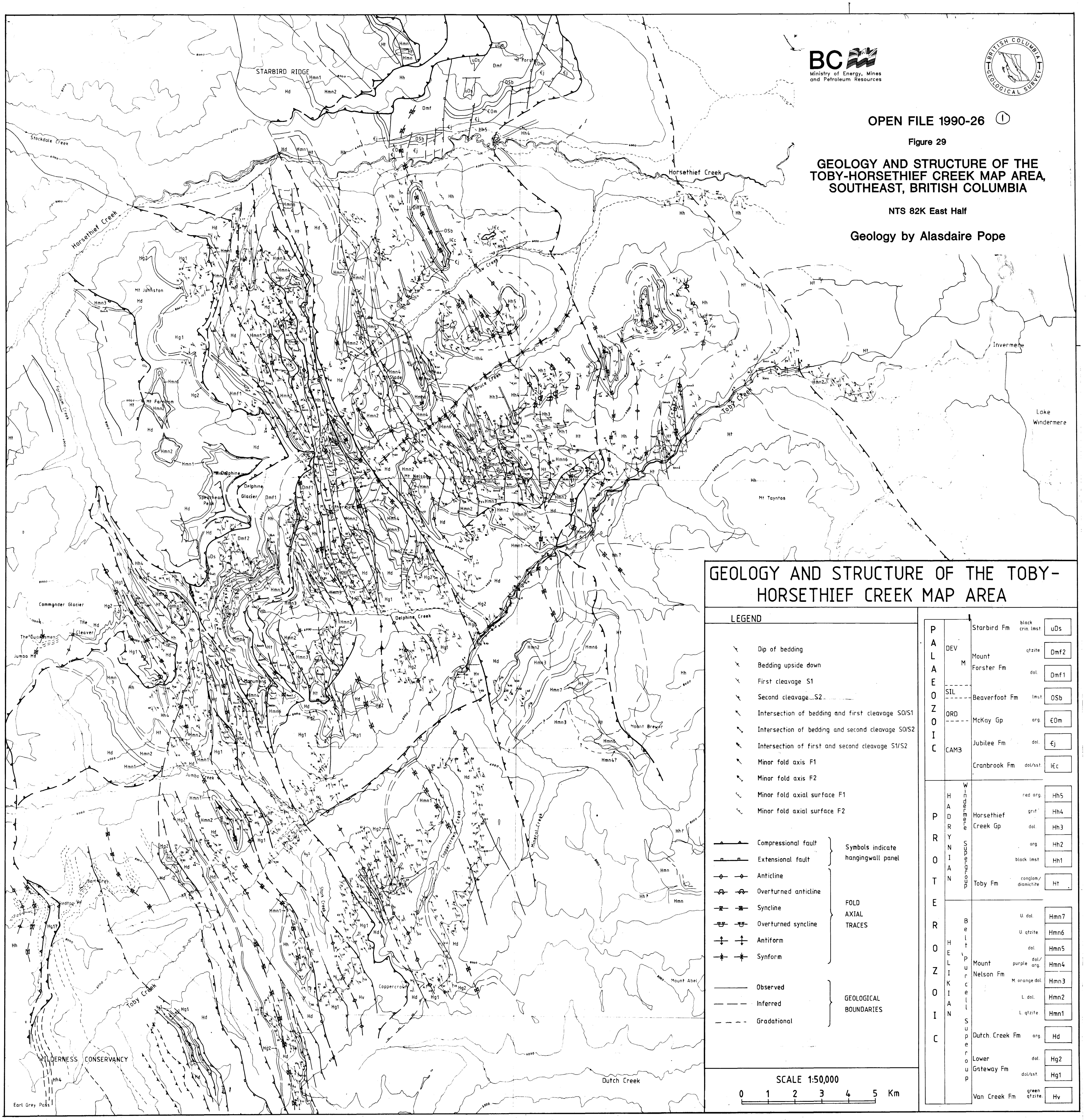
Thompson, B., Mercier, E. and Roots, C. (1987): Extension and its Influence on Canadian Cordilleran Passive Margin Evolution; *in* Continental Extensional Tectonics; *Geology Society of London*, M.P. Coward, J.F. Dewey and P.L. Hancock, Editors, Special Publication number 28, pages 408-417.

Tucker, M.E. (1982): Precambrian Dolomites: Petrographic and Isotopic Evidence That They Differ from Phanerozoic Dolomites; *Geology*, Volume 10, pages 7-12.

Vogt, J.H. and Stumpfl, E.F. (1987): Abra: A Stratabound Pb-Cu-Ba Mineralization in the Bangemall Basin, Western Australia; *Economic Geology*, Volume 82, No. 4, pages 805-825.

Walker, J.F. (1926): Geology and Mineral Deposits of the Windermere Map-area, British Columbia; *Canada Department of Mines*, Geological Survey, Memoir 148.

Walker, R.G. (1984): Shelf and Shallow Marine Sands; *in* Facies Models, R.G. Walker, Editor, 2nd Edition; *Geoscience Canada*, Reprint Series 1.


BC Ministry of Energy, Mines and Petroleum Resources
BRITISH COLUMBIA GEOLOGICAL SURVEY
OPEN FILE 1990-26 (1)
Figure 29
GEOLOGY AND STRUCTURE OF THE TOBY-HORSETHIEF CREEK MAP AREA, SOUTHEAST, BRITISH COLUMBIA
NTS 82K East Half
Geology by Alasdaire Pope
GEOLOGY AND STRUCTURE OF THE TOBY-HORSETHIEF CREEK MAP AREA
LEGEND
Dip of bedding
Bedding upside down
First cleavage S1
Second cleavage S2
Intersection of bedding and first cleavage S0/S1
Intersection of bedding and second cleavage S0/S2
Intersection of first and second cleavage S1/S2
Minor fold axis F1
Minor fold axis F2
Minor fold axial surface F1
Minor fold axial surface F2
Compressional fault
Extensional fault
Symbols indicate hangingwall panel
Anticline
Overturned anticline
Syncline
Overturned syncline
Antiform
Synform
FOLD AXIAL TRACES
Observed
Inferred
Gradational
GEOLOGICAL BOUNDARIES
SCALE 1:50,000
0 1 2 3 4 5 Km
PALAEOZOIC
DEV M
SIL
ORD
CAMB
Starbird Fm black crin lmst uDs
Mount Forster Fm qtzite Dmf2
dol. Dmf1
Beaverfoot Fm lmst OSb
McKay Gp arg. €Om
Jubilee Fm dol. €j
Cranbrook Fm dol/sst l€c
PROTEROZOIC
HADRYNIAN
Windermere Supergroup
Horsethief Creek Gp red arg Hh5
grit Hh4
dol. Hh3
arg Hh2
black lmst Hh1
Toby Fm conglom/diamictite Ht
HELIKIAN
Belt Purcell Supergroup
Mount Nelson Fm U dol Hmn7
U qtzite Hmn6
dol. Hmn5
purple dol/arg. Hmn4
M orange dol Hmn3
L dol. Hmn2
L qtzite Hmn1
Dutch Creek Fm arg Hd
Lower Gateway Fm dol. Hg2
dol/sst Hg1
Van Creek Fm green qtzite Hv
STARBIRD RIDGE
Stockdale Creek
Horsethief Creek
Mt Johnston
Farnham Creek
Mt Farnham
Delphine
Delphine Glacier
Spearhead Peak
Commander Glacier
The Cleaver
The Guardsmen
Jumbo Mt
Jumbo Creek
Monument
Delphine Creek
Mt Nelson
Bruce Creek
Law Creek
Toby Creek
Invermere
Lake Windermere
Mt Taynton
Mount Brewer
Mineral Creek
Coppercrown Creek
Coppercrown
Stark Creek
Mount Abel
Dutch Creek
Redtop Mt
WILDERNESS CONSERVANCY
Earl Grey Pass

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BRITISH COLUMBIA GEOLOGICAL SURVEY

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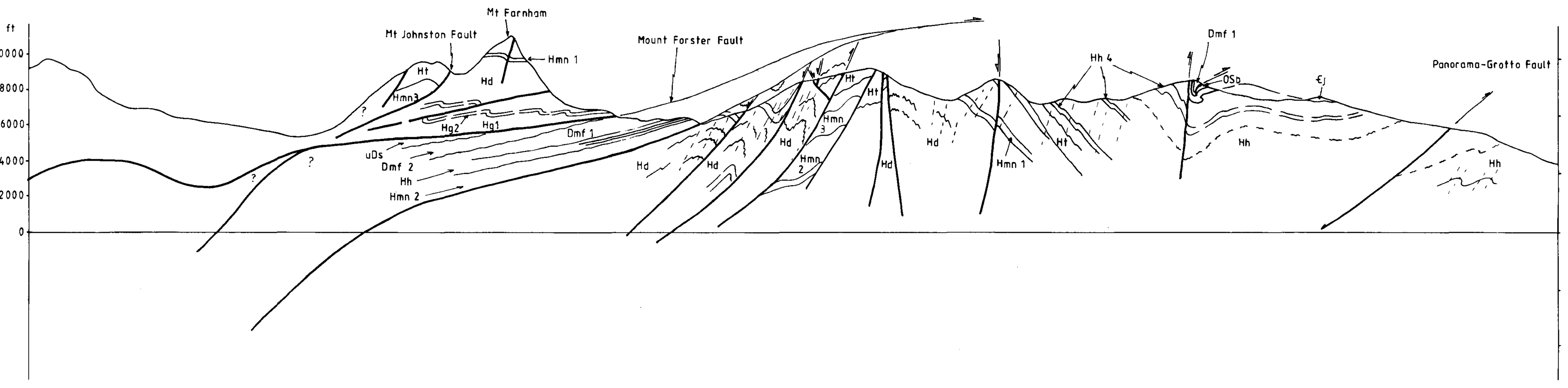
Figure 30
GEOLOGICAL CROSS SECTIONS TO ACCOMPANY FIGURE 29

NTS 82K East Half

Geology by Alasdaire Pope

Scale 1:50 000

Section 1



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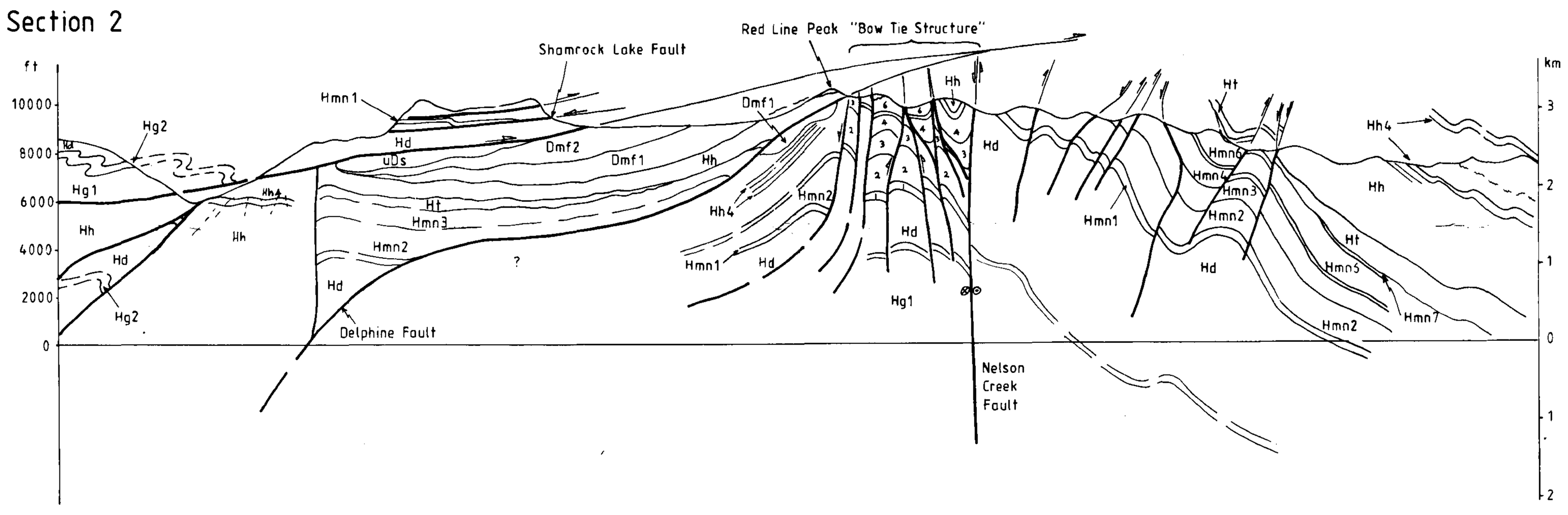

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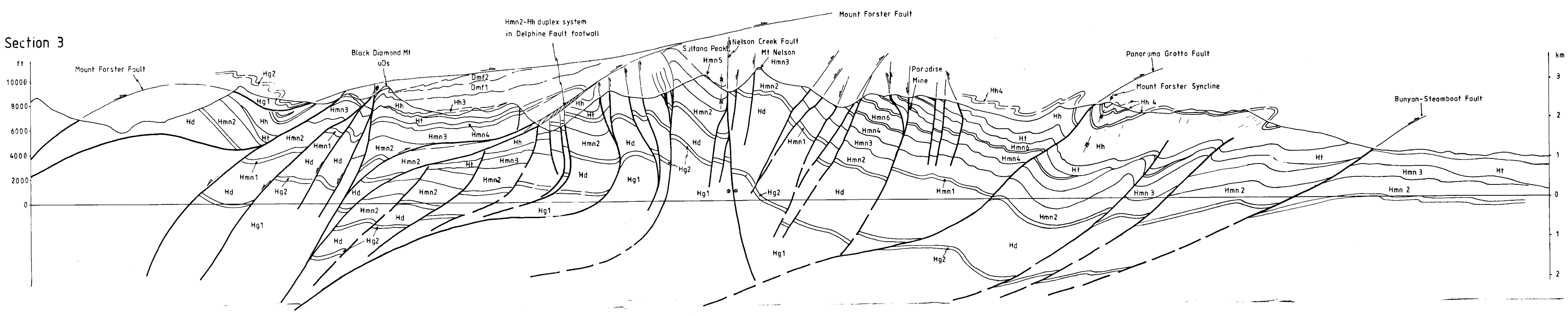

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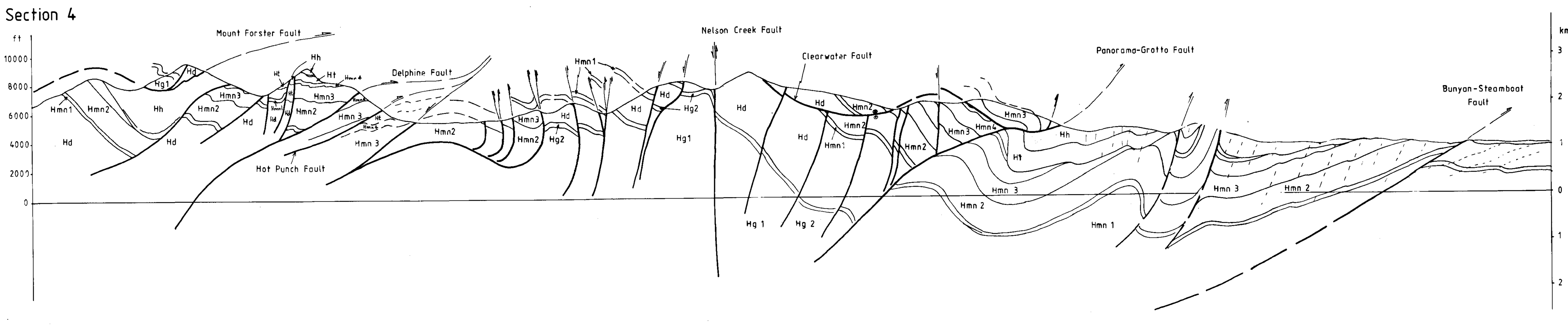

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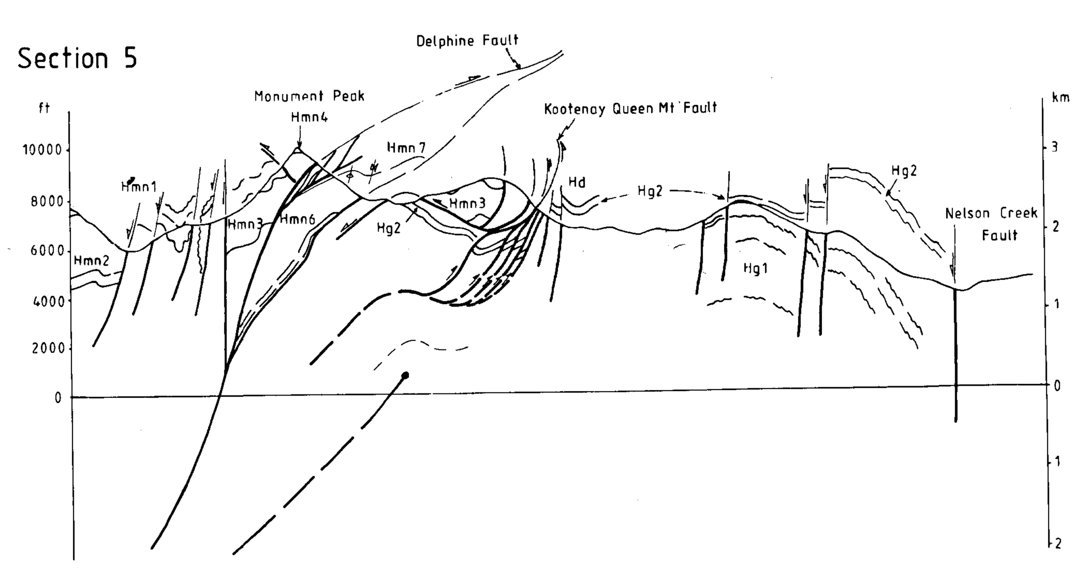

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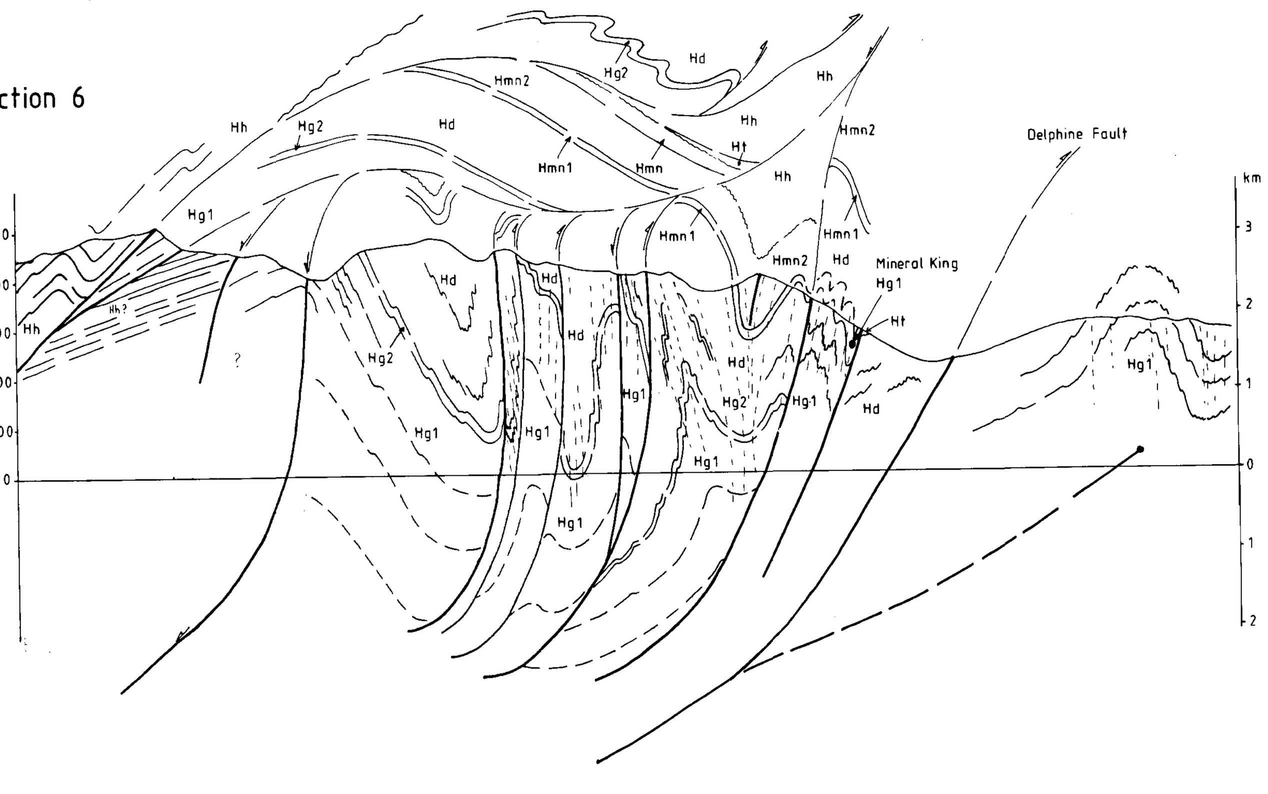

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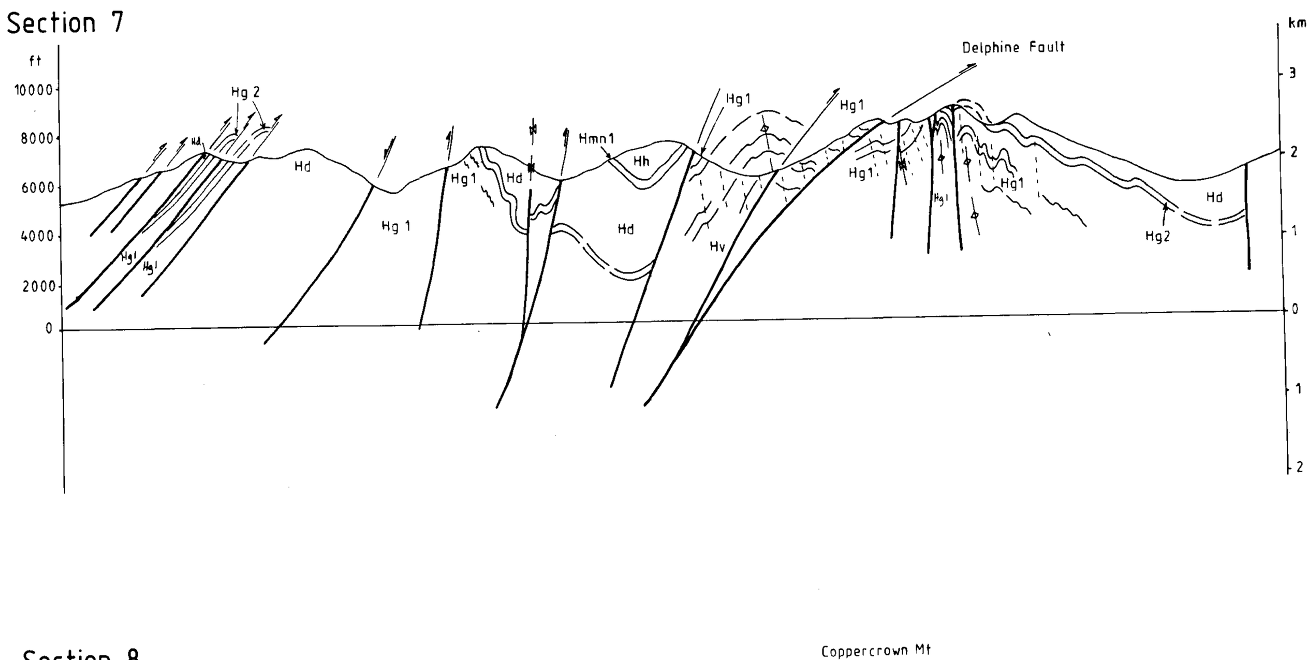

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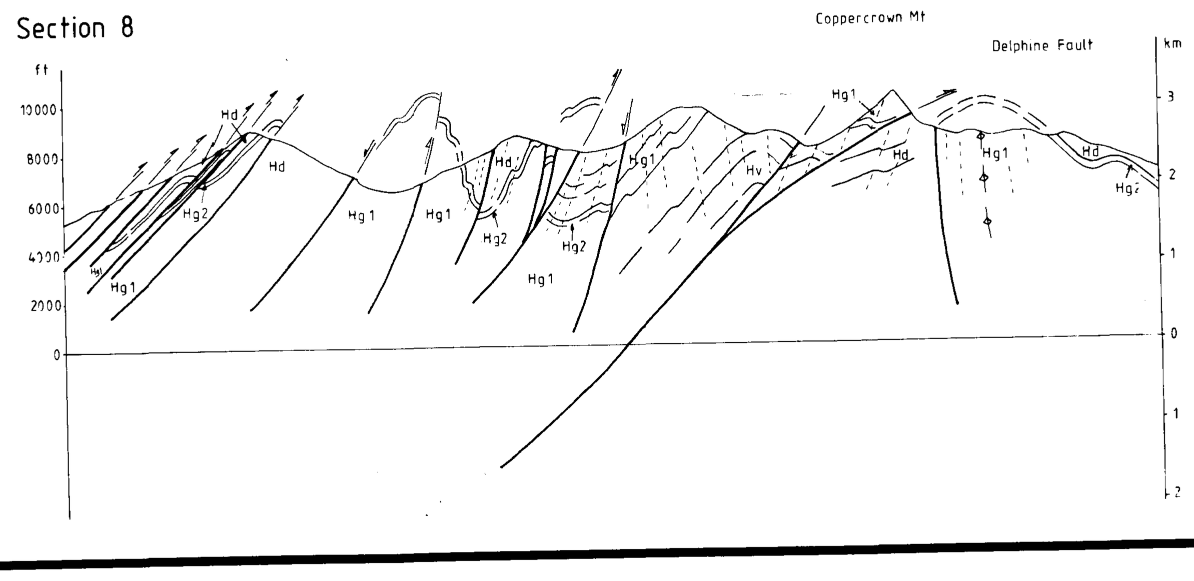

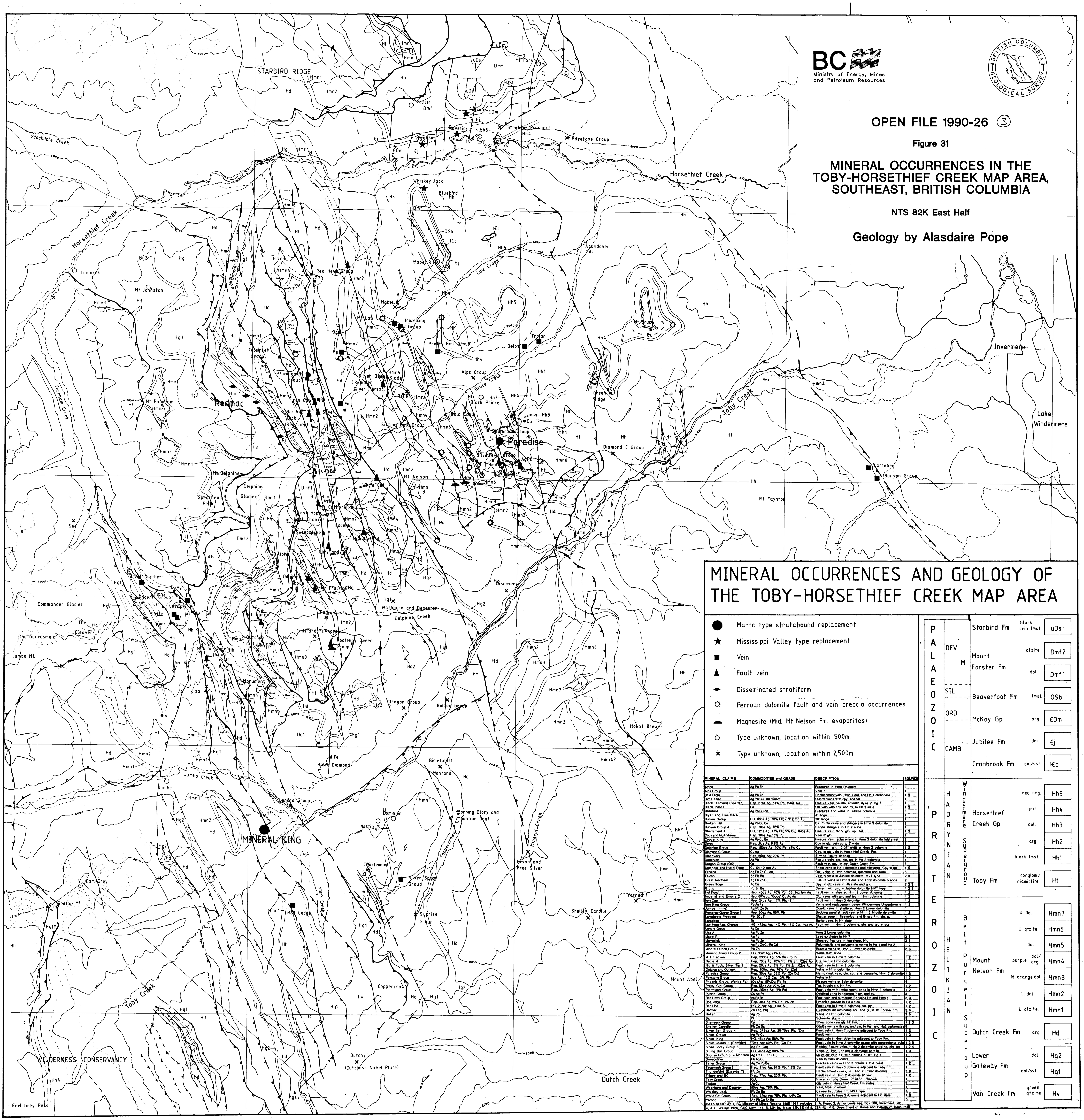

BC Ministry of Energy, Mines and Petroleum Resources

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Figure 31

MINERAL OCCURRENCES IN THE TOBY-HORSETHIEF CREEK MAP AREA, SOUTHEAST, BRITISH COLUMBIA

NTS 82K East Half

Geology by Alasdaire Pope

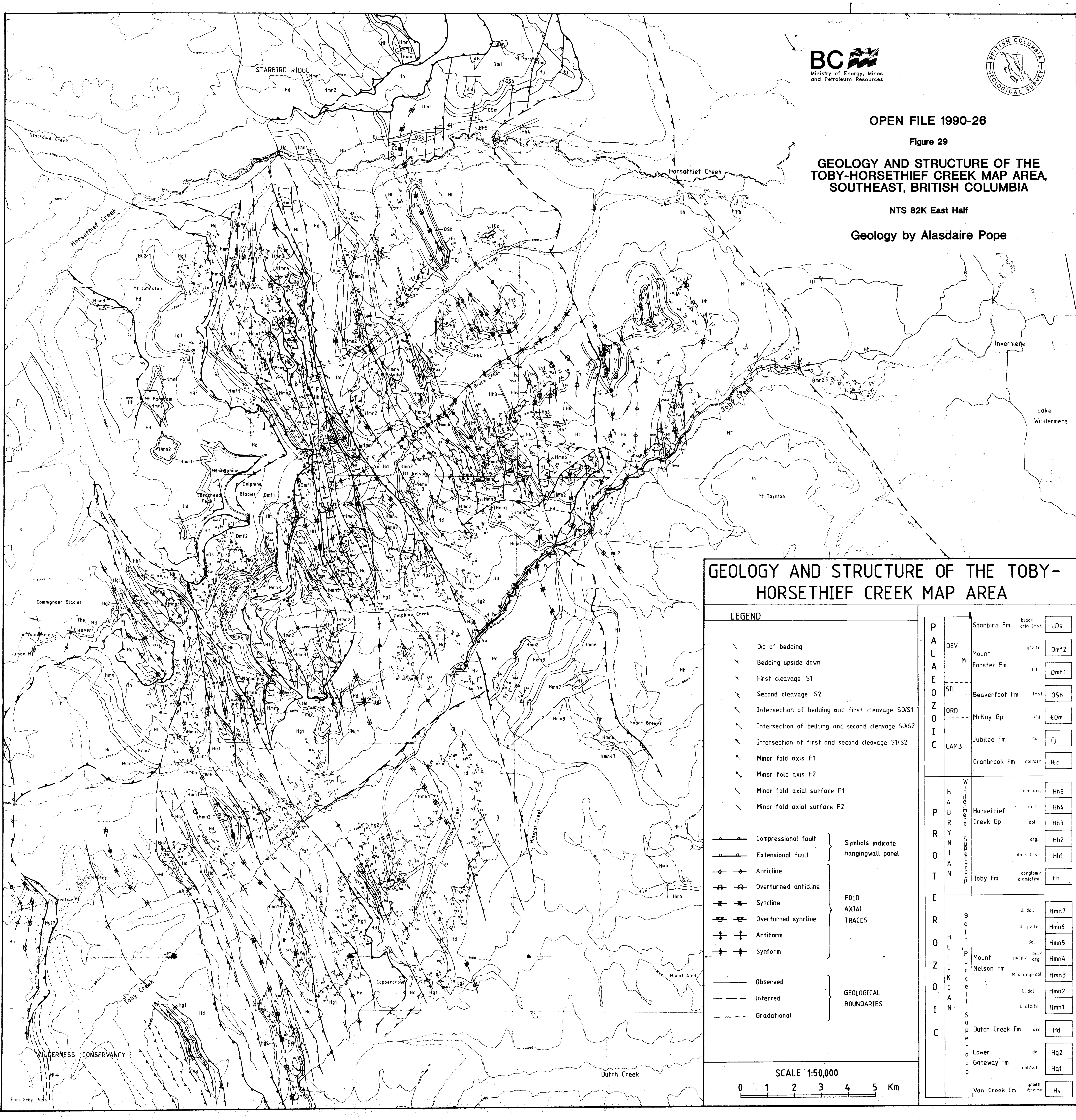
MINERAL OCCURRENCES AND GEOLOGY OF THE TOBY-HORSETHIEF CREEK MAP AREA

- ● Manto type stratabound replacement
- ★ Mississippi Valley type replacement
- ■ Vein
- ▲ Fault vein
- Disseminated stratiform
- Ferroan dolomite fault and vein breccia occurrences
- Magnesite (Mid. Mt Nelson Fm. evaporites)
- ○ Type unknown, location within 500m.
- × Type unknown, location within 2,500m.

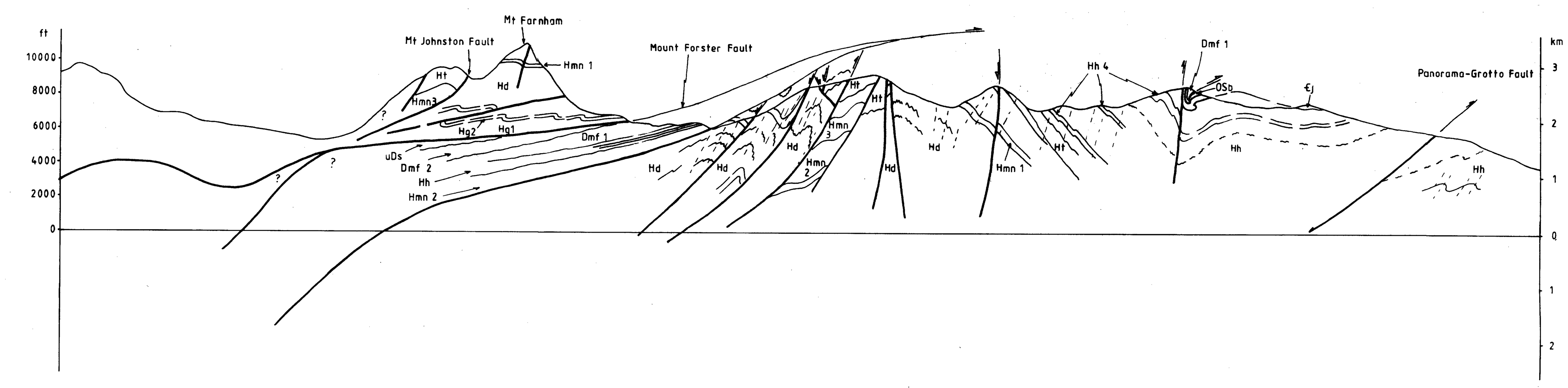
PALAEOZOIC	DEV	Starbird Fm	black crin. lmst	uDs
	DEV M	Mount Forster Fm	qtzite	Dmf2
			dol.	Dmf1
	SIL ORD	Beaverfoot Fm	lmst	OSb
	ORD	McKay Gp	arg.	€Om
	CAMB	Jubilee Fm	dol.	€j
		Cranbrook Fm	dol/sst.	l€c
PROTEROZOIC	HADRYNIAN Windermere Supergroup	Horsethief Creek Gp	red arg.	Hh5
			grit	Hh4
			dol.	Hh3
			arg	Hh2
			black lmst	Hh1
		Toby Fm	conglom/ diamictite	Ht
	HELIKIAN Belt Purcell Supergroup	Mount Nelson Fm	U. dol.	Hmn7
			U. qtzite	Hmn6
			dol	Hmn5
			purple dol/ arg.	Hmn4
			M. orange dol.	Hmn3
			L. dol	Hmn2
			L. qtzite.	Hmn1
		Dutch Creek Fm	arg.	Hd
		Lower Gateway Fm	dol.	Hg2
			dol/sst.	Hg1
		Van Creek Fm	green qtzite	Hv

MINERAL CLAIMS	COMMODITIES and GRADE	DESCRIPTION	SOURCE
Alpha	Ag Pb Zn	Fractures in Hmn Dolomite	5
Alps Group		Vein 10'	1
Bald Eagle	Ag Pb Zn	Replacement vein, Hmn 7 dol. and Hh 1 carbonate	4 3
Bimetallist	Ag Pb Cu, Au "Good"	Quartz veins with cpy. and tet.	1
Black Diamond (Spartan)	Rep. 27oz Ag; 61% Pb; .04oz Au	Fissure vein parallel chloritic dyke in Hg 1.	1
Black Prince	Cu	Qtz vein with cpy. and py. in Hh 2 slate	1 3
Bluebird	Ag Pb Cu Zn	Fractures and veins in Jubilee dolomite	5
Bryan and Free Silver		4' ledge	1
Bullion Group	HG. 80oz Ag; 76% Pb; < $12 ton Au	20' ledge	1
Broken Hill	Ag Pb Cu Ba	Ba Pb Cu veins and stringers in Hmn 3 dolomite	3
Bunyon Group 4	Rep. 18oz Ag; 16% Pb	Baryte stringers in Hh 2 slate	1
Charlemont 4	HG. 12oz Ag; 47% Pb; 5% Cu; .04oz Au	Fissure vein 3-15' gln. spl. tet.	1 3
Cody and McAndrews	Rep. 30oz Ag;65% Pb	Vein 8' gln.	1
Copper King	Ag Pb Cu Ba	Fissure Vein replacement in Hmn 3 dolomite fold crest	2
Delos	Rep. .8oz Ag; 9.6% Ag	Cpy in qtz. vein up to 5' wide	1
Delphine Group	Rep. 150oz Ag; 30% Pb; <5% Cu	Fault vein gln. 12-36" wide in Hmn 3 dolomite	1 2
Diamond C Group	Cu Au	Cpy. in qtz vein in Horsethief Creek Fm.	1
Discovery	Rep. 65oz Ag; 70% Pb	5' wide fissure deposit	1
Dominion	Ag Pb	Fissure vein, qtz. gln. tet. in Hg 2 dolomite	4
Dragon Group (OK)	Cu	Fault vein, cpy. in qtz. Dutch Creek Fm.	5
Dutchess and Nickel Plate	Cu $4-10 ton Au	Shear zone in Hg 1 dolomites and siltstones. Cpy in qtz	1 5
Excelda	Ag Pb Zn Cu Au	Qtz. veins in Hmn dolomite, quartzite and slate	5
Falcon	Zn Pb Ba	Vein breccia in Jubilee dolomite. MVT type	2 3
Great Northern	Ag Pb Zn Cu	Fissure veins in Hmn 3 dol. and Toby dolomite breccia	2
Green Ridge	Ag Cu	Cpy. in qtz veins in Hh slate and grit	2 3 5
Grotto	Pb Zn Ba	Cavern with gln. in Jubilee dolomite MVT type	1 2 3
Hot Punch	Rep. 45oz Ag; 40% Pb; .05-.1oz ton Au	Fault vein in sheared Hmn 2 Lower dolomite	1 2
Imperial and Empire 2	Rep. 60% pb; "Good" Cu Ag Au	Qtz. veins with gln. and tet. in Hmn dolomite	1 3
Iron Cap	Rep. 24oz Ag; 17% Pb; (Zn)	Fault vein in Hmn 3 dolomite	1 2
Iron King Group	Pb As Fe	Veins and replacement below Windermere Unconformity	1 2
Jumbo (mine)	Ag Pb Zn Ba	Quartz veins in shattered Hmn 2 Lower dolomite	1
Kootenay Queen Group 3	Rep. 50oz Ag; 65% Pb	Bedding parallel fault vein in Hmn 3 Middle dolomite	1 2
Larrabee's Prospect	Pb (Cu?)	Shatter zone in Beaverfoot and Brisco Fm. gln. py.	4
Larrabee	Ba	Barite veins in Hh slate	5
Last Hope Last Chance	HG. 472oz Ag; 14% Pb; 16% Cu; .1oz Au	Fault vein in Hmn 3 dolomite, gln. and tet. in qtz	1
Lenora Group	Ag Cu	?	1
Lisa A	Ag Pb Zn	Hmn 2 Lower dolomite	1
Mabel R	Ag Pb	Lead sulphates in Hh ?	3 5
Maverick	Ag Pb Zn	Sheared fracture in limestone, Hh.	3 5
Mineral King	Ag Pb Zn Cu Ba Cd	Polymetallic and polygenetic manto in Hg 1 and Hg 2	1 2
Mineral Queen Group	Pb Zn	Breccia veins in Hmn 2 Lower dolomite	2 3
Morning Glory Group 2	HG. 60oz Ag; 21% Cu	Veins 3-8" wide	1
M T Fraction	Rep. 230oz Ag; 5% Cu (Pb ?)	Fault vein in Hmn 3 dolomite	1 2
Nettie M	Rep. 70oz Ag; 70% Pb; 1% Zn; .02oz Au	Qtz. vein in Hmn dolomite	1
Nip & Tuck, Silver Tip 2	Rep. 26oz Ag; 8% Pb; 1% Zn; .02oz Au	Fault vein in Hmn 3 dolomite	1 2
Outcrop and Outlook	Rep. 100oz Ag; 70% Pb; (Zn)	Veins in Hmn dolomite	1
Paradise Group	Rep. 35oz Ag; 35% Pb; (Zn Cd)	Manto+fault vein, gln. spl. and cerussite, Hmn 7 dolomite	1 2
Paystone Group	5oz Ag; 12% Cu; 12% Pb	Veins in Hh	1 3
Phoenix Group, Worlds Fair	80ozAg; 15%Cu; Pb Ba	Fissure veins in Toby dolomite	4
Pretty Girl Group	Rep. 55oz Ag; 27% Cu	Tet. in vein qtz. Hh Fm.	1 2
Ptarmigan Group	Rep. 250oz Ag; (Pb Fe)	Fault vein with replacement pods in Hmn 2 dolomite	1 2
Puzzle Group	Cu Ag Pb	Oxidised zone in dolomite ? gln. and py.	3
Red Hawk Group	As Fe Ba	Fault vein and numerous Ba veins Hd and Hmn 1	2 3
Red Ledge	Rep. .8oz Ag; 6% Pb; 1% Zn	Limonitic gossan in Hd slates	1 2
Red Line	HG. 237oz Ag; .41oz Au	Fault vein in Hmn 3 dolomite. tet. py.	1 2
Redmac	Zn (Ag Pb)	Stratiform disseminated spl. and gl. in Mt Forster Fm.	2 6
Relief	Ag Pb	Veins in Hmn dolomite	3 5
Sec	W	Scheelite skarn	5
Shamrock Group	Cu	Shear zone vein qtz, Hh Fm.	1 2 3
Shelley Carrolle	Pb Cu Ba	Qtz/Ba veins with cpy. and gln. in Hg1 and Hg2 carbonates	5
Silver Belt Group 4	Rep. 218oz Ag; 30-70oz Pb; (Zn)	Fault vein in Hmn 7 dolomite adjacent to Toby Fm.	1 2
Silver Crown	Ag Pb Cu	Fault vein	1 2
Silver King	HG. 45oz Ag; 56% Pb	Fault vein in Hmn dolomite adjacent to Toby Fm.	1
Silver Queen 3 (Rambler)	70oz Ag; 60% Pb; (Cu Pb)	Fault vein in Hmn 2 dolomite assoc with metadolerite dyke	1 2 3
Silver Spray Group 5	Ag Pb (Cu)	Bedded fissure veins in Hg 2 dolomite anticline. gln. tet.	1 2 4
Sitting Bull Group	HG. 44oz Ag; 39% Pb	Veins in Hmn 3 dolomite cleavage parallel	1 3
Suprise Group 3, + Montana	Ag Pb Cu Zn (Au)	Milky qtz vein 14' with clumps of tet. Hg 1.	1
Sweepstake	Pb Ag Cu	Vein in Hmn dolomite	1
Tatler Group	Ag Cu Pb Ba	Fracture veins in Hmn 3 dolomite fold crest	1 2
Tecumseh Group 3	Rep. 11oz Ag; 61% Pb; 1.8% Cu	Fault vein in Hmn 3 dolomite adjacent to Toby Fm.	1
Thunderbird (Excelda ?)	Pb Zn	Replacement veining in Hmn 2 Lower dolomite	2 3
Tilbury and BC	Rep. 77oz Ag; 20% Pb;	Fault vein in Hmn 2 dolomite 9" vein	1 2
Toby Creek	Gold	Placer in Toby Creek. Position unknown	1
Trojan	Ag Cu	Qtz vein in Horsethief Creek Fm slates	3
Washburn and Deserter	80oz Ag; 75% Pb.	Vein, type unknown	1
Whiskey Jack	Pb Zn Ba	Cavern in Jubilee Fm. MVT type.	3
White Cat Group	Rep. 32oz Ag; 75% Pb; 1.4% Zn	Fault vein in Hmn 3 dolomite adjacent to Hd slate	1 3
Yomoc	Ag Pb Cu Zn Ba	?	5

DATA SOURCE: 1, BC Ministry of Mines Reports 1865-1967 Inclusive; 2, A. Pope; 3, Arthur Louie esq. Box 508, Invermere BC; 4, J. F. Walker 1926, GSC Mem 148; 5, Min Inv Maps 82K/SE (M1), 82K/NE (M1), Department of Mines and Petroleum Resources


BC
Ministry of Energy, Mines and Petroleum Resources
BRITISH COLUMBIA GEOLOGICAL SURVEY
OPEN FILE 1990-26
Figure 29
GEOLOGY AND STRUCTURE OF THE TOBY-HORSETHIEF CREEK MAP AREA, SOUTHEAST, BRITISH COLUMBIA
NTS 82K East Half
Geology by Alasdaire Pope
GEOLOGY AND STRUCTURE OF THE TOBY-HORSETHIEF CREEK MAP AREA
LEGEND
Dip of bedding
Bedding upside down
First cleavage S1
Second cleavage S2
Intersection of bedding and first cleavage S0/S1
Intersection of bedding and second cleavage S0/S2
Intersection of first and second cleavage S1/S2
Minor fold axis F1
Minor fold axis F2
Minor fold axial surface F1
Minor fold axial surface F2
Compressional fault
Extensional fault
Symbols indicate hangingwall panel
Anticline
Overturned anticline
Syncline
Overturned syncline
Antiform
Synform
FOLD AXIAL TRACES
Observed
Inferred
Gradational
GEOLOGICAL BOUNDARIES
SCALE 1:50,000
0 1 2 3 4 5 Km
PALAEOZOIC
DEV M
SIL
ORD
CAMB
Starbird Fm black crin lmst uDs
Mount Forster Fm qtzite Dmf2
dol. Dmf1
Beaverfoot Fm lmst OSb
McKay Gp arg. €Om
Jubilee Fm dol €j
Cranbrook Fm dol/sst l€c
PROTEROZOIC
HADRYNIAN
Windermere Supergroup
Horsethief Creek Gp red arg. Hh5
grit Hh4
dol. Hh3
arg. Hh2
black lmst Hh1
Toby Fm conglom/diamictite Ht
HELIKIAN
Belt Purcell Supergroup
Mount Nelson Fm U. dol. Hmn7
U. qtzite Hmn6
dol Hmn5
purple dol/arg. Hmn4
M. orange dol. Hmn3
L. dol. Hmn2
L. qtzite Hmn1
Dutch Creek Fm arg. Hd
Lower Gateway Fm dol. Hg2
dol/sst. Hg1
Van Creek Fm green qtzite Hv
STARBIRD RIDGE
Stockdale Creek
Horsethief Creek
Mt Johnston
Mt Farnham
Farnham Creek
Mt Delphine
Delphine Glacier
Spearhead Peak
Mt Nelson
Mt Catherine
Bruce Creek
Slade
Law Creek
Invermere
Toby Creek
Lake Windermere
Mt Taynton
Commander Glacier
The Cleaver
The Guardsmen
Jumbo Mt
Monument
Jumbo Creek
Delphine Creek
Mount Brewer
Mineral Creek
Coppercrown Creek
Coppercrown
Shark Creek
Mount Abel
Earl Grey
Redtop Mt
Toby Creek
WILDERNESS CONSERVANCY
Earl Grey Pass
Dutch Creek

Section 1



Ministry of Energy, Mines and Petroleum Resources

BRITISH COLUMBIA GEOLOGICAL SURVEY

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Figure 30

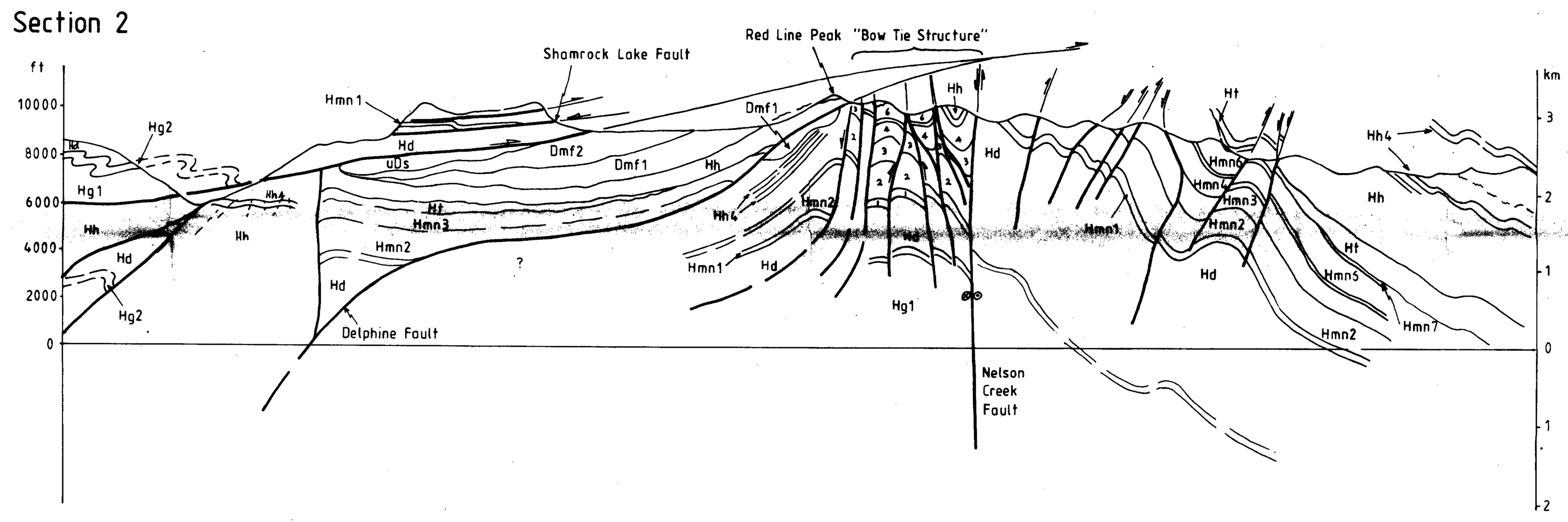
GEOLOGICAL CROSS SECTIONS TO ACCOMPANY FIGURE 29

NTS 82K East Half

Geology by Alasdaire Pope

Scale 1:50 000

Section 2



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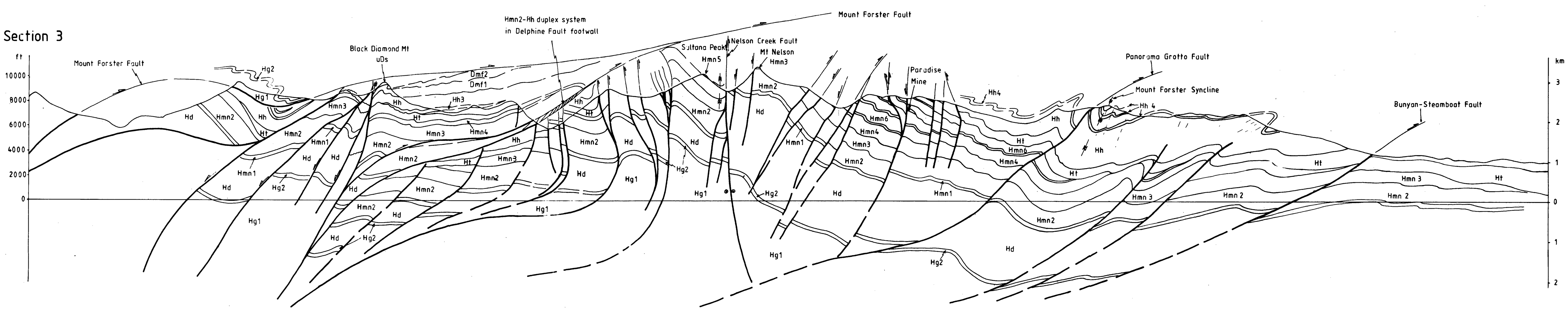

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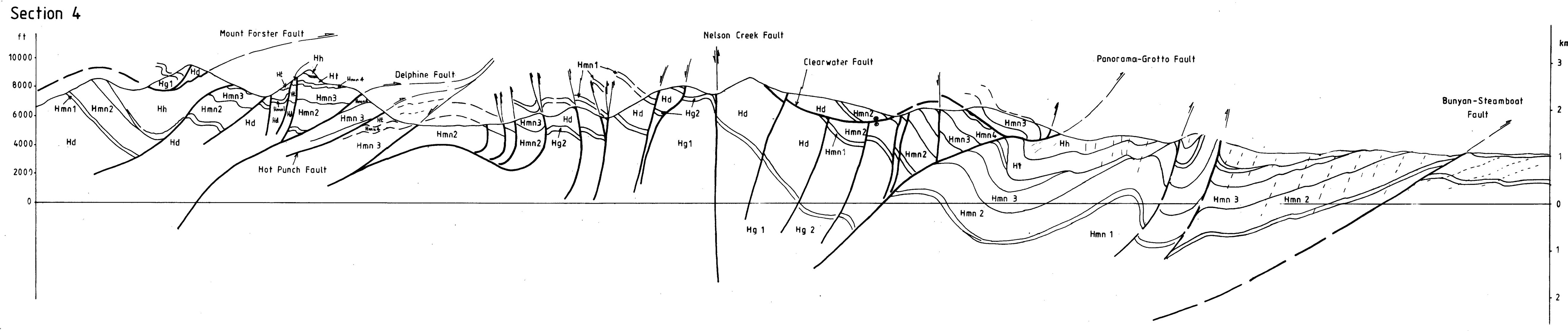

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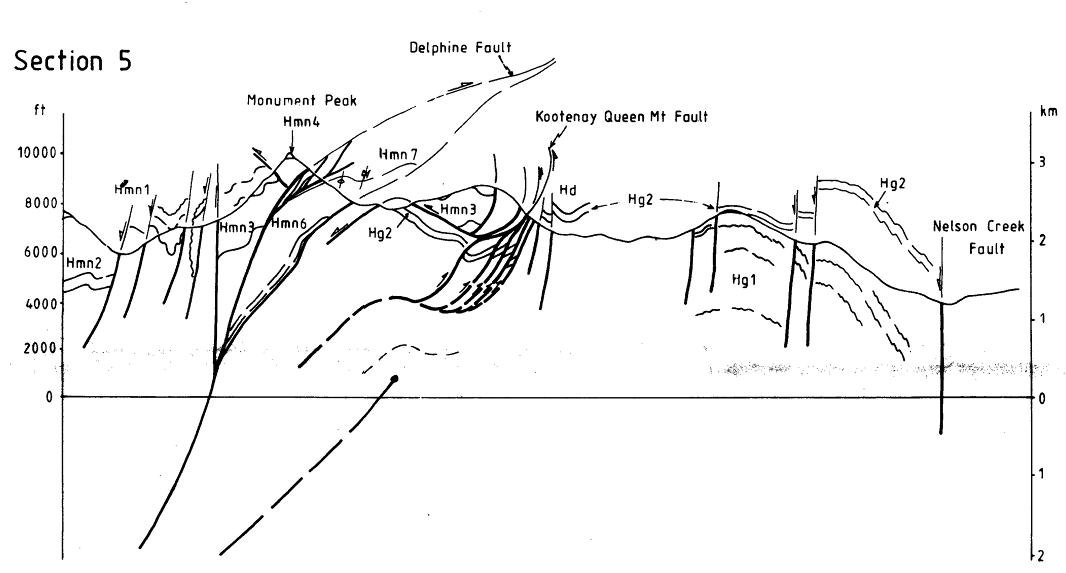

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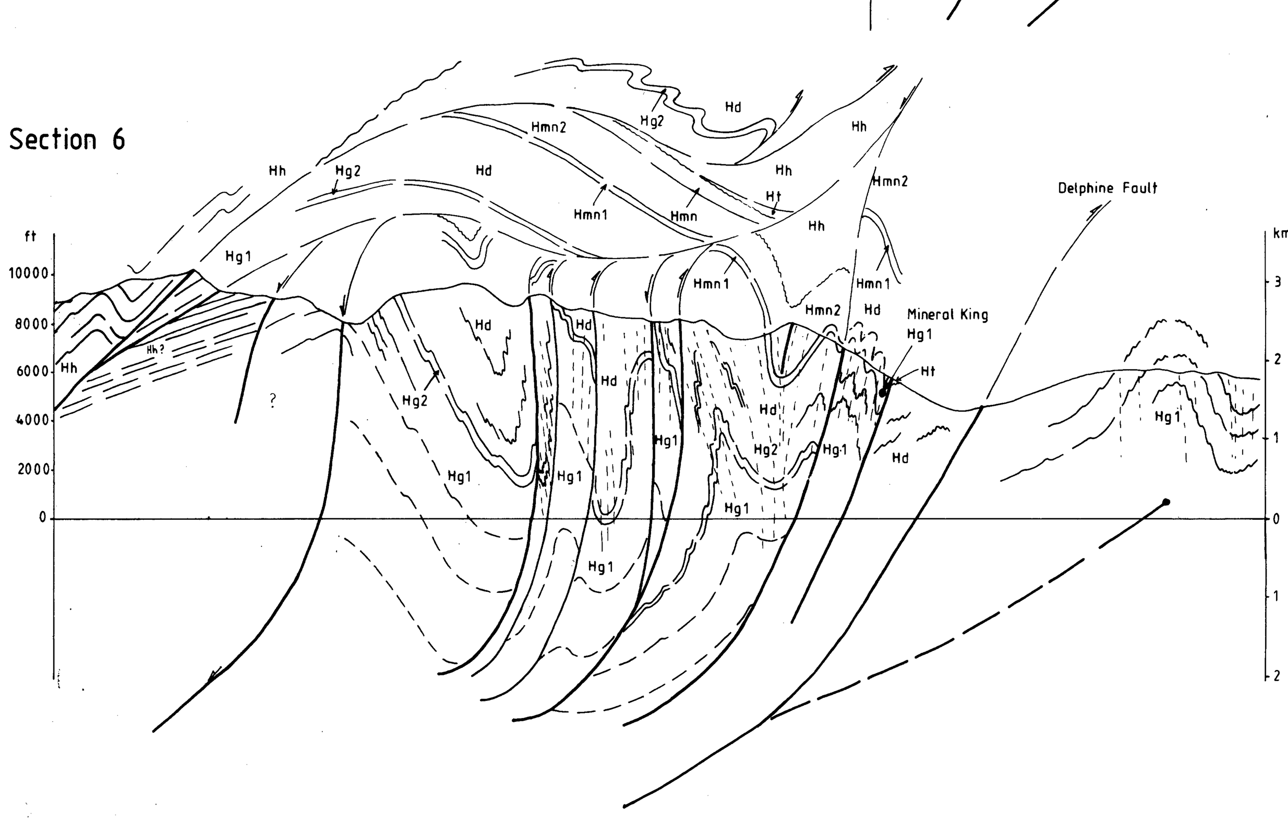

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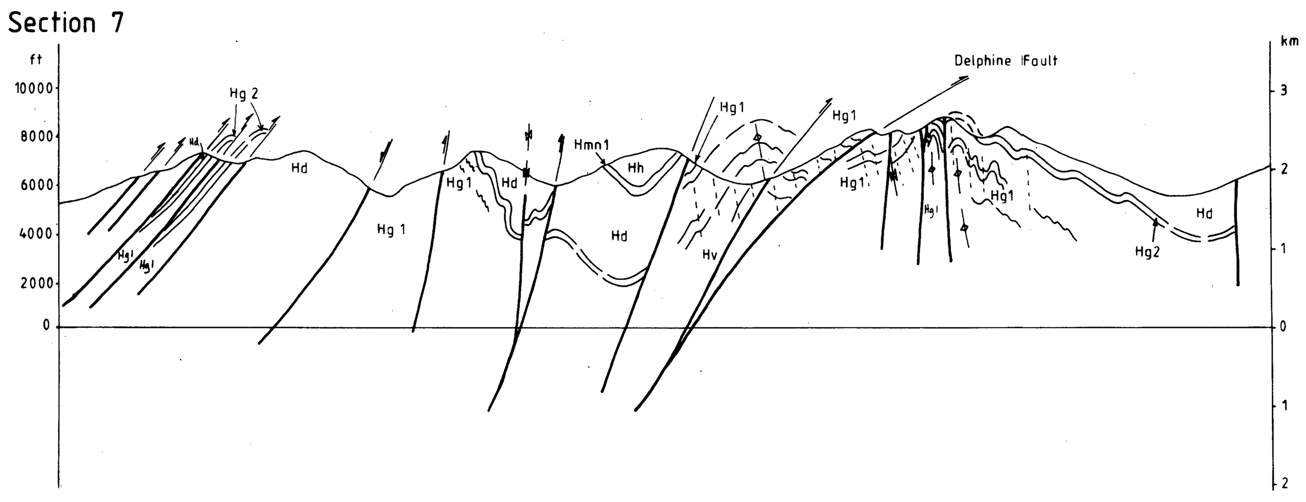

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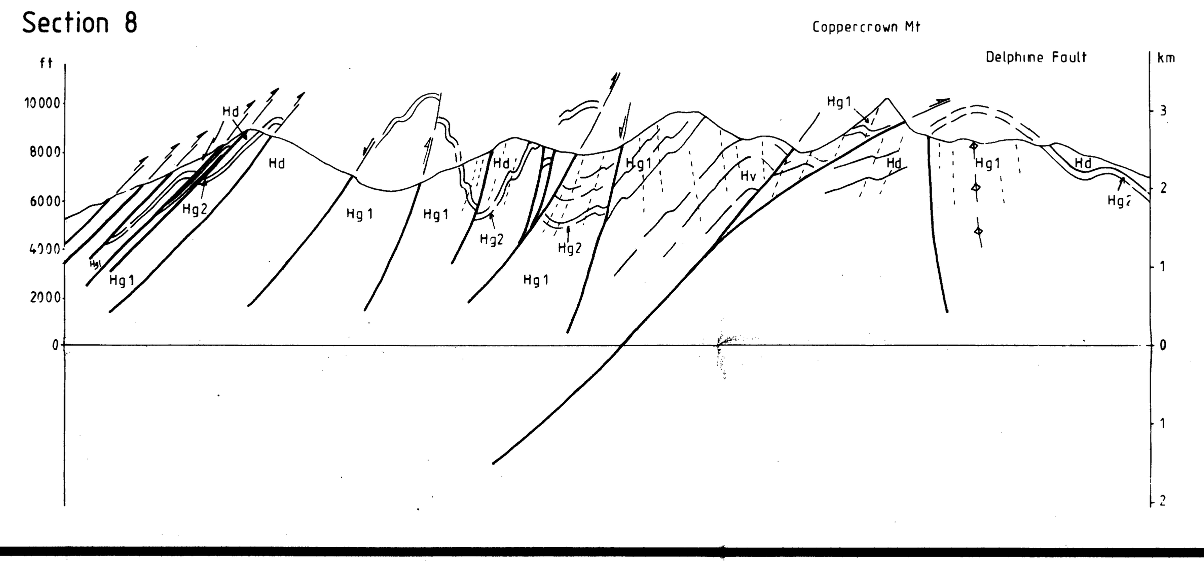

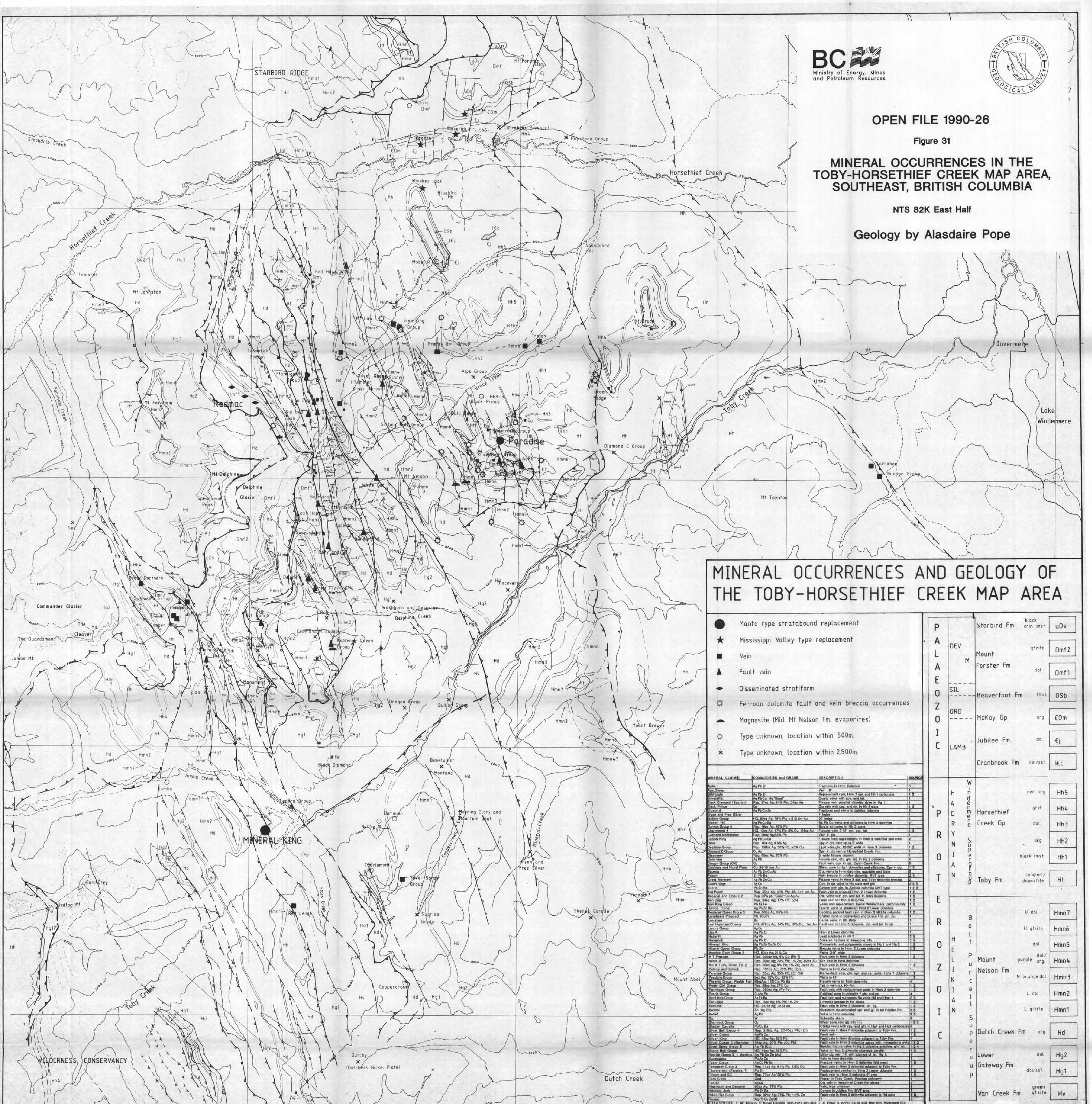

BC Ministry of Energy, Mines and Petroleum Resources

British Columbia Geological Survey

OPEN FILE 1990-26

Figure 31

MINERAL OCCURRENCES IN THE TOBY-HORSETHIEF CREEK MAP AREA, SOUTHEAST, BRITISH COLUMBIA

NTS 82K East Half

Geology by Alasdaire Pope

MINERAL OCCURRENCES AND GEOLOGY OF THE TOBY-HORSETHIEF CREEK MAP AREA

- ● Manto type stratabound replacement
- ★ Mississippi Valley type replacement
- ■ Vein
- ▲ Fault vein
- ◆ Disseminated stratiform
- ☼ Ferroan dolomite fault and vein breccia occurrences
- ◓ Magnesite (Mid. Mt Nelson Fm. evaporites)
- ○ Type unknown, location within 500m.
- × Type unknown, location within 2,500m.

PALAEOZOIC	DEV		Starbird Fm	black crin. lmst	uDs
		M	Mount Forster Fm	qtzite	Dmf2
				dol.	Dmf1
	SIL / ORD		Beaverfoot Fm	lmst	OSb
	ORD		McKay Gp	arg	€Om
	CAM3		Jubilee Fm	dol.	€j
			Cranbrook Fm	dol/sst.	l€c
PROTEROZOIC	HADRYNIAN	Windermere Supergroup	Horsethief Creek Gp	red arg	Hh5
				grit	Hh4
				dol.	Hh3
				arg	Hh2
				black lmst	Hh1
			Toby Fm	conglom/diamictite	Ht
	HELIKIAN	Belt Purcell Supergroup	Mount Nelson Fm	U. dol	Hmn7
				U. qtzite	Hmn6
				dol.	Hmn5
				purple dol/arg.	Hmn4
				M. orange dol	Hmn3
				L. dol.	Hmn2
				L. qtzite	Hmn1
			Dutch Creek Fm	arg	Hd
			Lower Gateway Fm	dol	Hg2
				dol/sst.	Hg1
			Van Creek Fm	green qtzite	Hv

MINERAL CLAIMS	COMMODITIES and GRADE	DESCRIPTION	SOURCE
Alpha	Ag Pb Zn	Fractures in Hmn Dolomite	5
Alps Group		Vein 10'	1
Bald Eagle	Ag Pb Zn	Replacement vein, Hmn 7 dol. and Hh 1 carbonate	4 3
Bimetallist	Ag Pb Cu, Au "Good"	Quartz veins with cpy. and tet.	1
Black Diamond (Spartan)	Rep. 27oz Ag; 61% Pb; .04oz Au	Fissure vein parallel chloritic dyke in Hg 1.	1
Black Prince	Cu	Qtz vein with cpy. and py. in Hh 2 slate	1 3
Bluebird	Ag Pb Cu Zn	Fractures and veins in Jubilee dolomite	5
Bryan and Free Silver		4' ledge	1
Bullion Group	HG. 80oz Ag; 76% Pb; < $12 ton Au	20' ledge	1
Broken Hill	Ag Pb Cu Ba	Ba Pb Cu veins and stringers in Hmn 3 dolomite	3
Bunyon Group 4	Rep. 16oz Ag; 16% Pb	Baryte stringers in Hh 2 slate	1
Charlemont 4	HG. 12oz Ag; 47% Pb; 5% Cu; .04oz Au	Fissure vein 3-15' gln. spl. tet.	1 3
Cody and McAndrews	Rep. 30oz Ag;65% Pb	Vein 8' gln.	1
Copper King	Ag Pb Cu Ba	Fissure Vein replacement in Hmn 3 dolomite fold crest	2
Delos	Rep. .8oz Ag; 9.6% Ag	Cpy in qtz. vein up to 5' wide	1
Delphine Group	Rep. 150oz Ag; 30% Pb; <5% Cu	Fault vein gln. 12-36" wide in Hmn 3 dolomite	1 2
Diamond C Group	Cu Au	Cpy. in qtz vein in Horsethief Creek Fm.	1
Discovery	Rep. 65oz Ag; 70% Pb	5' wide fissure deposit	1
Dominion	Ag Pb	Fissure vein, qtz. gln. tet. in Hg 2 dolomite	4
Dragon Group (OK)	Cu	Fault vein, cpy. in qtz. Dutch Creek Fm.	5
Dutchess and Nickel Plate	Cu $4-10 ton Au	Shear zone in Hg 1 dolomites and siltstones. Cpy in qtz	1 5
Excelda	Ag Pb Zn Cu Au	Qtz. veins in Hmn dolomite, quartzite and slate	5
Falcon	Zn Pb Ba	Vein breccia in Jubilee dolomite. MVT type	2 3
Great Northern	Ag Pb Zn Cu	Fissure veins in Hmn 3 dol. and Toby dolomite breccia	2
Green Ridge	Ag Cu	Cpy. in qtz veins in Hh slate and grit	2 3 5
Grotto	Pb Zn Ba	Cavern with gln. in Jubilee dolomite MVT type	1 2 3
Hot Punch	Rep. 45oz Ag; 40% Pb; .05-.1oz ton Au	Fault vein in sheared Hmn 2 Lower dolomite	1 2
Imperial and Empire 2	Rep. 60% pb; "Good" Cu Ag Au	Qtz. veins with gln. and tet. in Hmn dolomite	1 3
Iron Cap	Rep. 24oz Ag; 17% Pb; (Zn)	Fault vein in Hmn 3 dolomite	1 2
Iron King Group	Pb As Fe	Veins and replacement below Windermere Unconformity	1 2
Jumbo (mine)	Ag Pb Zn Ba	Quartz veins in shattered Hmn 2 Lower dolomite	1
Kootenay Queen Group 3	Rep. 50oz Ag; 65% Pb	Bedding parallel fault vein in Hmn 3 Middle dolomite	1 2
Larrabee's Prospect	Pb (Cu?)	Shatter zone in Beaverfoot and Brisco Fm. gln. py.	4
Larrabee	Ba	Barite veins in Hh slate	5
Last Hope Last Chance	HG. 472oz Ag; 14% Pb; 16% Cu; .1oz Au	Fault vein in Hmn 3 dolomite, gln. and tet. in qtz	1
Lenora Group	Ag Cu	?	1
Lisa A	Ag Pb Zn	Hmn 2 Lower dolomite	1
Mabel R	Ag Pb	Lead sulphates in Hh ?	3 5
Maverick	Ag Pb Zn	Sheared fracture in limestone, Hh.	3 5
Mineral King	Ag Pb Zn Cu Ba Cd	Polymetallic and polygenetic manto in Hg 1 and Hg 2	1 2
Mineral Queen Group	Pb Zn	Breccia veins in Hmn 2 Lower dolomite	2 3
Morning Glory Group 2	HG. 60oz Ag; 21% Cu	Veins 3-6" wide	1
M T Fraction	Rep. 230oz Ag; 5% Cu (Pb ?)	Fault vein in Hmn 3 dolomite	1 2
Nettie M	Rep. 70oz Ag; 70% Pb; 1% Zn; .02oz Au	Qtz. vein in Hmn dolomite	1
Nip & Tuck, Silver Tip 2	Rep. 26oz Ag; 8% Pb; 1% Zn; .02oz Au	Fault vein in Hmn 3 dolomite	1 2
Outcrop and Outlook	Rep. 100oz Ag; 70% Pb; (Zn)	Veins in Hmn dolomite	1
Paradise Group	Rep. 35oz Ag; 35% Pb; (Zn Cd)	Manto+fault vein, gln. spl. and cerussite, Hmn 7 dolomite	1 2
Paystone Group	5oz Ag; 12% Cu; 12% Pb	Veins in Hh	1 3
Phoenix Group, Worlds Fair	80ozAg; 15%Cu; Pb Ba	Fissure veins in Toby dolomite	4
Pretty Girl Group	Rep. 55oz Ag; 27% Cu	Tet. in vein qtz. Hh Fm.	1 2
Ptarmigan Group	Rep. 250oz Ag; (Pb Fe)	Fault vein with replacement pods in Hmn 2 dolomite	1 2
Puzzle Group	Cu Ag Pb	Oxidised zone in dolomite ? gln. and py.	3
Red Hawk Group	As Fe Ba	Fault vein and numerous Ba veins Hd and Hmn 1	2 3
Red Ledge	Rep. .8oz Ag; 6% Pb; 1% Zn	Limonitic gossan in Hd slates	1 2
Red Line	HG. 237oz Ag; .41oz Au	Fault vein in Hmn 3 dolomite. tet. py.	1 2
Redmac	Zn (Ag Pb)	Stratiform disseminated spl. and gl. in Mt Forster Fm.	2 6
Relief	Ag Pb	Veins in Hmn dolomite	3 5
Sec	W	Scheelite skarn	5
Shamrock Group	Cu	Shear zone vein qtz, Hh Fm.	1 2 3
Shelley Carrolle	Pb Cu Ba	Qtz/Ba veins with cpy. and gln. in Hg1 and Hg2 carbonates	5
Silver Belt Group 4	Rep. 218oz Ag; 30-70oz Pb; (Zn)	Fault vein in Hmn 7 dolomite adjacent to Toby Fm.	1 2
Silver Crown	Ag Pb Cu	Fault vein	1 2
Silver King	HG. 45oz Ag; 56% Pb	Fault vein in Hmn dolomite adjacent to Toby Fm.	1
Silver Queen 3 (Rambler)	70oz Ag; 60% Pb; (Cu Pb)	Fault vein in Hmn 2 dolomite assoc with metadolerite dyke	1 2 3
Silver Spray Group 5	Ag Pb (Cu)	Bedded fissure veins in Hg 2 dolomite anticline. gln. tet.	1 2 4
Sitting Bull Group	HG. 44oz Ag; 39% Pb	Veins in Hmn 3 dolomite cleavage parallel	1 3
Suprise Group 3, + Montana	Ag Pb Cu Zn (Au)	Milky qtz vein 14' with clumps of tet. Hg 1.	1
Sweepstake	Pb Ag Cu	Vein in Hmn dolomite	1
Tatler Group	Ag Cu Pb Ba	Fracture veins in Hmn 3 dolomite fold crest	1 2
Tecumseh Group 3	Rep. 11oz Ag; 61% Pb; 1.8% Cu	Fault vein in Hmn 3 dolomite adjacent to Toby Fm.	1
Thunderbird (Excelda ?)	Pb Zn	Replacement veining in Hmn 2 Lower dolomite	2 3
Tilbury and BC	Rep. 77oz Ag; 20% Pb;	Fault vein in Hmn 2 dolomite 9" vein	1 2
Toby Creek	Gold	Placer in Toby Creek. Position unknown	1
Trojan	Ag Cu	Qtz vein in Horsethief Creek Fm slates	3
Washburn and Deserter	80oz Ag; 75% Pb.	Vein, type unknown	1
Whiskey Jack	Pb Zn Ba	Cavern in Jubilee Fm. MVT type.	3
White Cat Group	Rep. 32oz Ag; 75% Pb; 1.4% Zn	Fault vein in Hmn 3 dolomite adjacent to Hd slate	1 3
Yornoc	Ag Pb Cu Zn Ba	?	5

DATA SOURCE: 1, BC Ministry of Mines Reports 1885-1967 inclusive; 2, A. Pope; 3, Arthur Louie esq. Box 508, Invermere BC; 4, J. F. Walker 1926, GSC Mem 148; 5, Min Inv Maps 82K/SE (M1), 82J/NE (M1), Department of Mines and Petroleum Resources.