PRELIMINARY GEOLOGY OF THE TUTSHI LAKE AREA, NORTHWESTERN BRITISH COLUMBIA

(104M/15)

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KEYWORDS: Regional geology, Tutshi Lake, Stikine terrane, Nisling terrane, Cache Creek terrane, Llewellyn fault, Laberge Group, Stuhini Group, Boundary Ranges metamorphics, mineral occurrences.

INTRODUCTION

Geological mapping at 1:25 000 scale (compiled at 1:50 000) and geochemical stream sediment sampling in the Tutshi Lake area were conducted by a four-man crew between mid-June and early September of 1987. The purpose of the program was to construct an accurate 1:50 000 geological map and to evaluate the involvement of ore-forming processes in the deposition and later deformation of rocks that range from Proterozoic(?) to Tertiary age within the Tutshi Lake area. Results of the geochemical program and 1:50 000-scale geological map are scheduled for release in open file format in February 1988. This study was undertaken, in accordance with Geological Survey Branch objectives, to create a high quality geological database to benefit industry and stimulate exploration activity in British Columbia.

The area is part of an anomalous antimony-arsenic province extending southward from the Venus mine to beyond the old Engineer mine (Figure 1-20-1) with sporadic, but commonly high gold and silver values (Schroeter, 1986). High antimony background values are likely an artifact of abundant stibnite-bearing veins which appear related to a late Cretaceous intrusive event.

Sheared quartz-carbonate alteration zones, locally hosting lead-zinc mineralization within Triassic volcanics, are associated with a major, long-lived, dextral oblique-slip fault system that bisects the map area. This structural setting is analogous to the Polaris Taku and Engineer mines to the south.

ACCESS AND PHYSIOGRAPHY

Access to the field area is via the Klondike Highway, 120 kilometres south of Whitehorse. An extensive lake system provides good boat access to most of the low-lying areas; the remainder is accessible by multi-day hikes or by helicopter.

The region is mountainous with approximately 1500 metres of relief produced by alpine glaciation; relatively small remnants of a once extensive ice cover still remain. Widespread glacial features occur at all elevations; an upland alluvial plateau at 1500 metres exists east of Bennett Lake, with eskers found on valley floors at 700 metres.

Snow covers much of the alpine areas (above 1200 metres) until early July, and flurries can be expected at higher elevations throughout the summer.

REGIONAL GEOLOGIC SETTING

Parts of three terranes are evident in the map area: Stikinia, Nisling and Cache Creek (Wheeler, 1987; *see* Figure 1-20-1). At this latitude, Stikinia is dominated by rocks of the Whitehorse trough. Within the study area the Llewellyn fault zone (Bultman, 1979; Schroeter, 1986), a major dextral transcurrent extension of the King Salmon fault, forms the western boundary of most of Stikinia and the eastern boundary of the Nisling terrane. Minor erosional remnants of Laberge Group and younger strata east of the Llewellyn fault rest on mainly pre-Permian metamorphic rocks here termed the "Boundary Ranges metamorphics" of the Nisling terrane. This metamorphic terrane is bounded on the west by hornblende-biotite granites[1] and granodiorites of the Coast crystalline complex. Within and adjacent to the map area, it underlies the eastern flank of the Boundary Ranges and marks the transition between the Coast and the Intermontane belts.

Strata of interpreted Cache Creek affinity are juxtaposed with the Upper Cretaceous Montana Mountain volcanic complex by a possible northern extension of the Nahlin fault with considerable west-side-down motion.

The oldest rocks within the area are strongly deformed pre-Permian schists and allochthonous Mississippian Cache Creek lithologies which contain an anomalous Verbeekinid fusulinid fauna of presumable Tethyan origin (Monger, 1975, 1977). Laberge trough strata overlie pre-Permian basement rocks with profound unconformity, and together have suffered extensive deformation sometime between middle or late Jurassic to late Cretaceous time. Montana Mountain volcanic rocks of probable Late Cretaceous age post-date folding, but are crosscut by a late Cretaceous to Tertiary quartz monzonite body (Figure 1-20-2; Table 1-20-1).

LAYERED ROCKS

"BOUNDARY RANGES METAMORPHICS" (PPM)

The Boundary Ranges metamorphics are exposed in a gently plunging, tight to open fold pair within a northwest-trending belt 4 kilometres wide (Domain II of Figure 1-20-3). These metamorphic rocks are identical to those described by Werner (1977, 1978) south of the Wann River (Figure 1-20-1), and may also correlate with deformed strata to the north, previously known as the Yukon Group (Cairnes, 1913; Christie, 1957, 1958) and later incorporated under the name "Yukon crystalline terrane" (Tempelman-Kluit, 1976). Tempelman-Kluit suggests that the name Yukon Group be abandoned in favour of names that more accurately

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[1] IUGS modal classification scheme of Streckeisen (1973) is used throughout.

British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1987, Paper 1988-1.

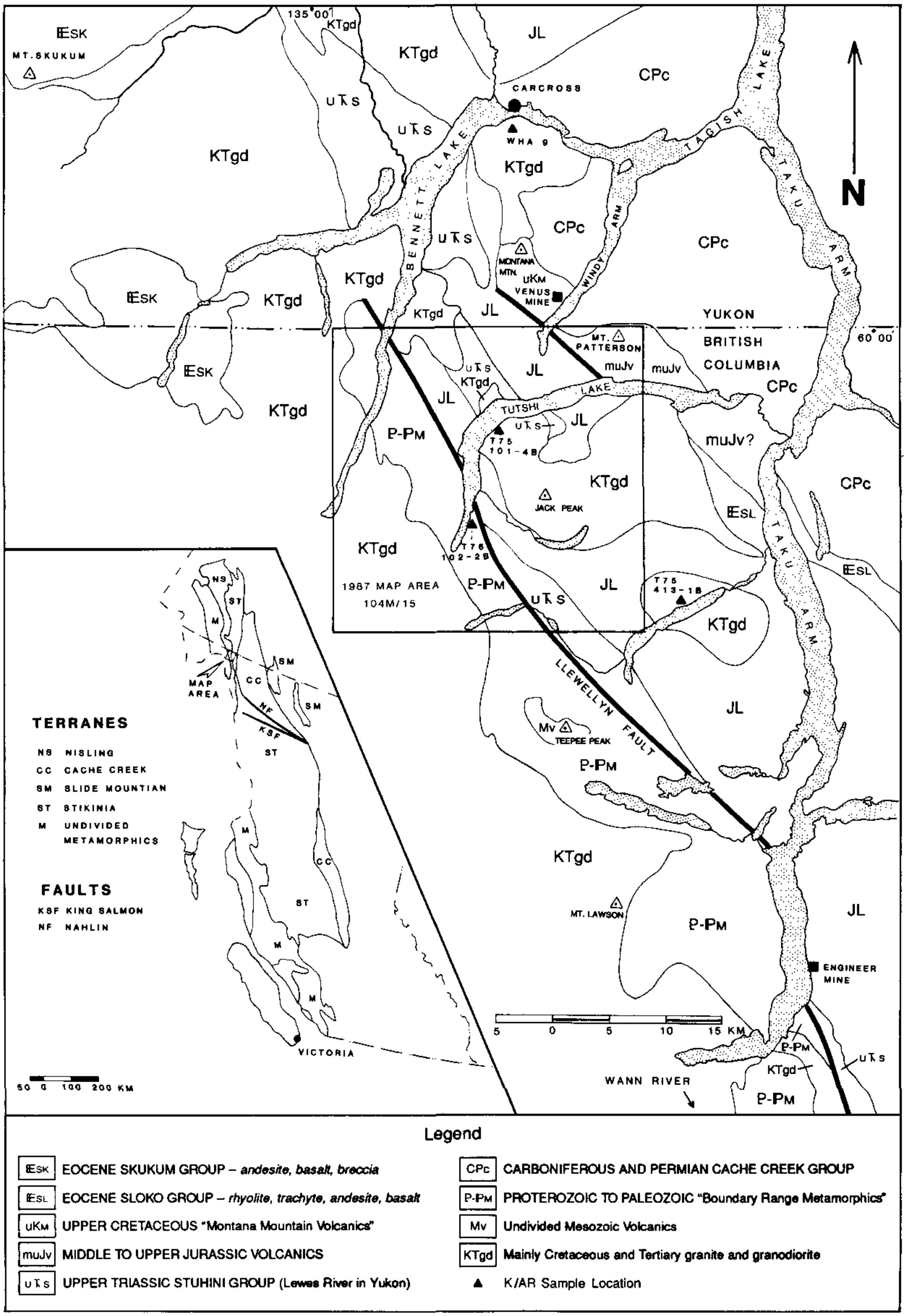


Figure 1-20-1. Regional geologic and tectonic setting of the Tutshi Lake map area (104M/15).

TABLE 1-20-1
ROCK FORMATIONS

Era	Period of Epoch	Formation	Lithology
Quaternary		Quaternary alluvium	Poorly sorted sands, gravels and till
Mesozoic	Upper Cretaceous?	Montana Mountain volcanics	Intermediate to felsic pyroclastics and flows; typically altered and orange weathering; crosscut by 64-Ma intrusive*
		Fault or intrusive contact**	
	Upper Cretaceous	Coast intrusions	K-feldspar megacrystalline granite varying to alkaline granite and granodiorite; dated at 77.9 and 89.5 Ma***
		Chilled intrusive contact	
		STIKINIA	
	Probable lower to mid-Jurassic	Volcanics	Dominantly variegated pyroclastic lapilli tuffs; rhyolitic tuffs; bladed-feldspar porphyry flows
		Unconformity and/or gradational	
	Lower Jurassic	Laberge Group, Inklin Formation	Siltstones, arenaceous wackes, argillites and conglomerates; rarely fossiliferous
		Erosional unconformity	
	Upper Triassic	Stuhini Group	Green pyroxene feldspar porphyry tuffs and breccias; variegated tuffs; minor tuffaceous sediments, limestone
		Erosional unconformity	
	Triassic?	Early intrusives	Polyphase granodiorite to alkali granite, typically sheared, foliated and/or altered
		Intrusive and/or faulted	
Paleozoic/ Proterozoic		**NISLING TERRANE**	
	pre-Permian (maximum age unknown)	"Boundary Ranges metamorphics"	Argillaceous siltstones, greywackes, lesser basalts, felsic pyroclastcis and carbonates; variably metamorphosed to upper greenschist grade
		Not observed — separate terranes assumed in fault contact, if at all	
		CACHE CREEK	
	Mississippian	Nakina Formation	Massive greenschist, altered basic flows and tuffaceous sediments

*Morrison *et al.* (1979)
**Observation of Roots (1980)
***Bultman (1979)

indicate the stratigraphic heterogeneity of this metamorphic package. Current nomenclature (Wheeler, 1987) includes the Boundary Ranges suite in the Nisling terrane.

Within 104M/15 these rocks are metamorphosed to upper greenschist facies although, in places, no secondary mineral development was observed in outcrop. Protoliths are variable but dominated by siltstone, lesser basalts and intermediate pyroclastic rocks and minor carbonates.

Insufficient petrographic work has been done to outline isograds or to fully characterize the secondary mineralogy. Extremely rapid changes in metamorphic mineralogy reflect not only varying protoliths, but also differing metamorphic grade. It appears that isogradic surfaces may be folded, or alternatively, faults subparallel to the Llewellyn fault may juxtapose metamorphic rocks of different grades.

The degree of deformation varies from locally nonexistent to more typically strong and pervasive. Schistosity or compositional banding may display polyphase, coaxial as well as disharmonic folding. Multiple phases of veining and microfaulting suggest a long metamorphic history (Plate 1-20-1; *see* also "Structure"). Some concordant quartz segregations and lesser discordant veins obtain thicknesses of 1 metre and may be boudined. These are generally barren, but just north of the Yukon border host pyrite, tellurides and free gold (Wheeler, 1961). Similarly, to the south, the Tonya (104M/9W) and Rupert (104M/8W) mineralized quartz vein showings have yielded assays of 23.31 grams per tonne gold and 237.6 grams per tonne silver respectively.

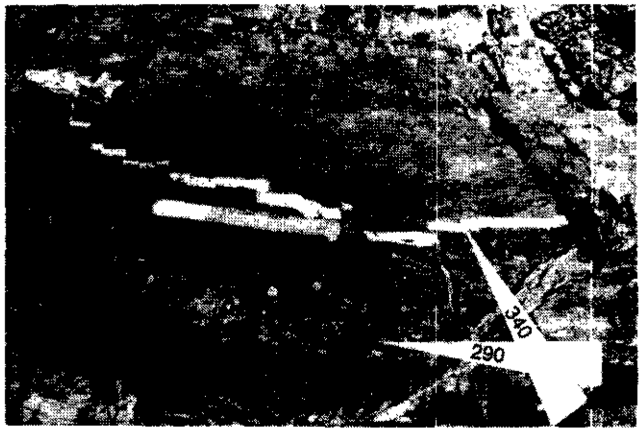


Plate 1-20-1. An outcrop of Boundary Ranges metamorphics on the ridges above and north of Skelly Lake. An earlier 290-degree fabric is paralleled by a 3-centimetre-thick quartz vein. The foliation displays the initial phases of transposition to the dominant regional structural trend of 340 degrees. Three-pound sledge hammer (38.5 centimetres long) for scale.

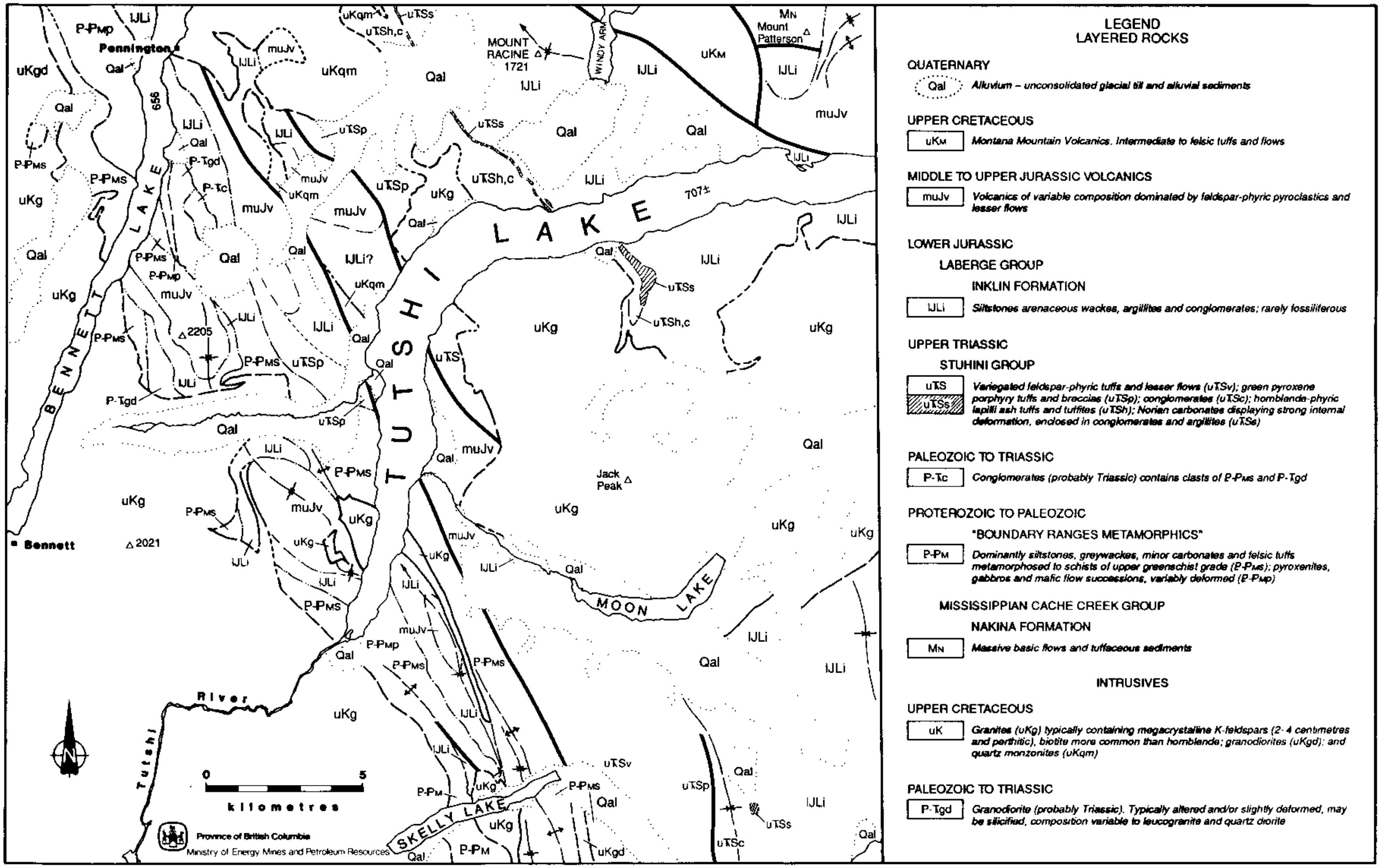


Figure 1-20-2. Preliminary simplified geology map of the Tutshi Lake area (104M/15).

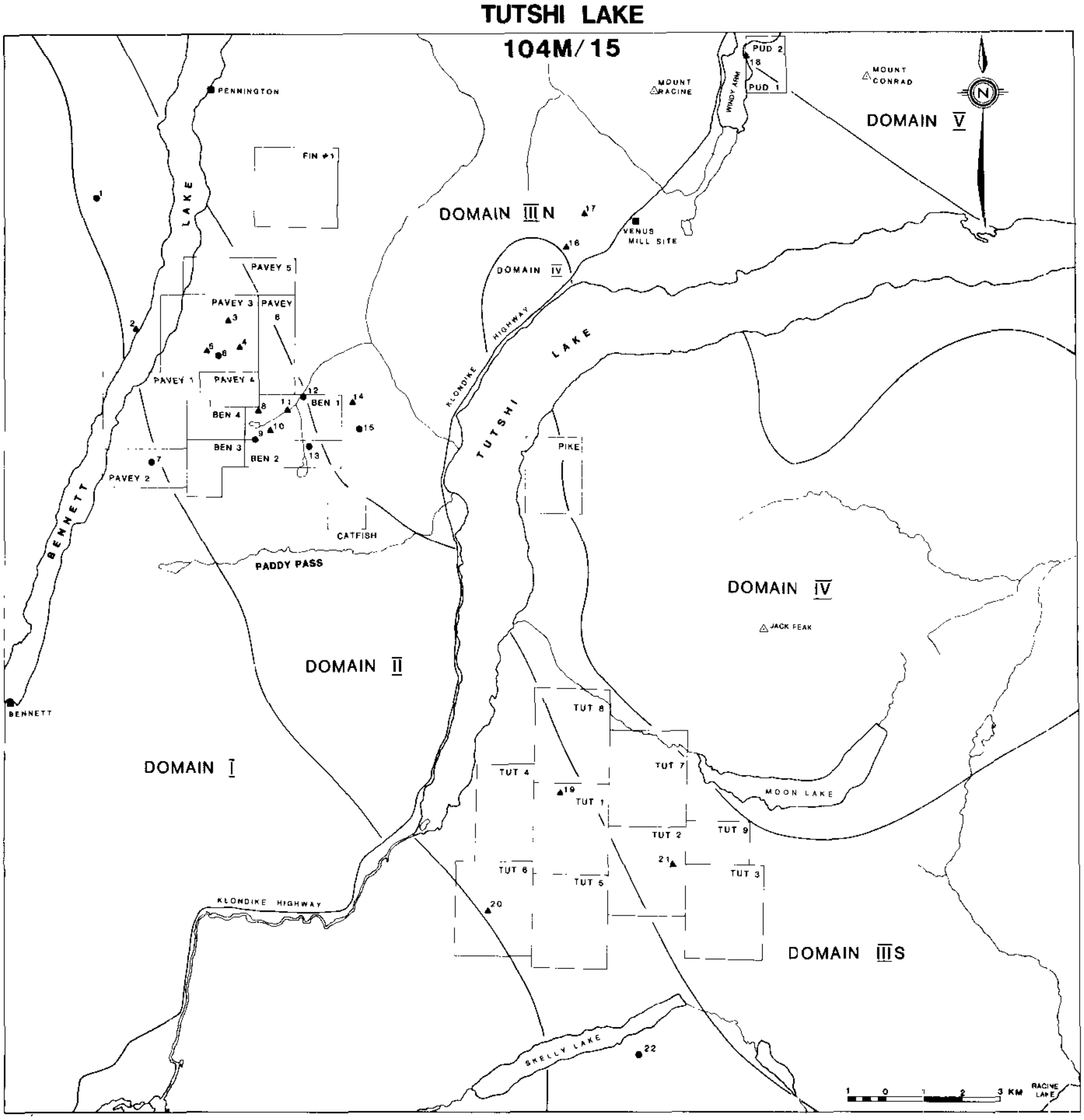


Figure 1-20-3. Distribution of current claims from Mineral Titles Reference Map 104M/15 and geologic domains. MINFILE localities are shown by solid triangles and circles (locations accurate within 250 and 500 metres respectively).

Due to structural complexity, little information on the general thickness, shape or facies relationships between various protoliths has been deciphered. Carbonate layers up to 5 metres or more thick are distinctive horizons within the metamorphic package, but are difficult to follow due to small offsets and shearing that produce discontinuous and podiform bodies. These strata were intruded by granodiorites, gabbros and pyroxenites prior to their final deformation.

The exact age of these rocks is difficult to assess; however, rocks of the Nisling terrane (Tempelman-Kluit, 1976) from north of the British Columbia – Yukon border are correlated with Paleozoic and Proterozoic sequences of the Omineca Belt. A porphyritic and foliated granodiorite that intrudes the metamorphic rocks was radiometrically dated by Bultman (1979) at 215 ± 5 Ma, yielding an upper age limit for the metamorphic suite.

EARLY INTRUSIVES (PTRgd)

A diverse assemblage of pre-upper Triassic intrusive bodies occurs both within Domain II and on its faulted

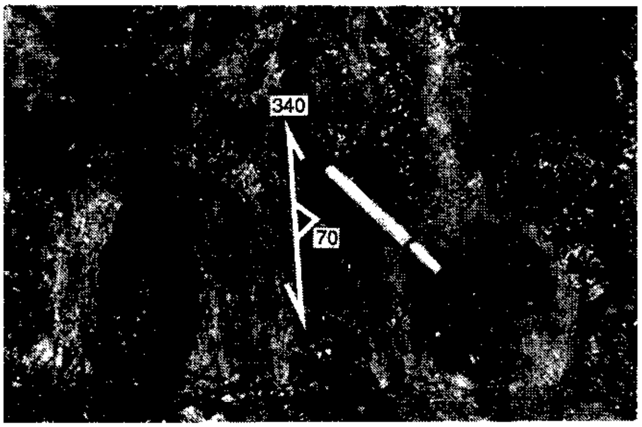


Plate 1-20-2. Llewellyn fault zone where exposed in a creek bed near the east end of Skelly Lake. A 10-metre or more wide zone of foliated fault gouge hosts aligned blocks of altered pre-upper Triassic intrusive rocks. Pen for scale is 13 centimetres long; view to the north-northwest.

eastern margin. Altered quartz diorites to quartz-veined leucogranites within the Llewellyn fault zone display a weak to strong foliation (Plate 1-20-2). Veins are broken and rotated within a matrix containing fine-grained gouge and brecciated and milled, subrounded to elongate, granitoid blocks. Mafic minerals (hornblende ?) comprise up to 20 per cent of the rocks and are altered to chlorite and epidote, while feldspars are clay altered.

Potassium feldspar porphyritic hornblende granodiorite to quartz monzonite is found mainly west of Bennett Lake and may be related to the "porphyritic granodiorite" of Bultman (1979) dated at 215±5 Ma. It is foliated with aligned hornblende (20 per cent, up to 1.5 centimetres) and potassium feldspar phenocrysts up to 2 centimetres (25 per cent), within a plagioclase-rich matrix containing minor epidote, quartz and chlorite.

Pyroxenites to pyroxene gabbros occur adjacent to Bennett Lake. Pyroxenites are holocrystalline, and in places are carbonatized or serpentinized with minor chrysotile. Gabbros weather red and may display rare primary intrusive layering with chloritized pyroxenes in a white plagioclase-rich matrix, or may be sheared so that pyroxenes are boudined between layers of granulated plagioclase.

CACHE CREEK GROUP (MN)

Along the eastern side of Windy Arm, Monger (1975) describes a structureless sequence of massive flows as part of the Nakina Formation, one of the oldest units of the Cache Creek Group. Farther southeast along structural trend with these rocks, underlying Mount Patterson in the northeast part of the map area, a similar package of fine-grained, green, nondescript volcanics crop out. They display a network of chlorite veinlets and irregular dioritic patches and rare, sparsely pyroxene-porphyritic zones. Despite their altered external appearance, these rocks are surprisingly fresh upon microscopic analysis. Alteration is evident in the matrix with the presence of pumpellyite, prehnite(?), chlorite, epidote and sphene; however, unexpected in deformed rocks of this age, essentially pristine plagioclase and augite are also present.

The precise age of these rocks is not known, although if correlative with other Nakina Formation rocks of Monger (1975), they are probably Mississippian. Their contact with overlying rocks of Laberge Group affiliation is problematic. It is disrupted, but not penetratively deformed, and if rotated blocks at the contact preserve the original contact relationships, as appears to be the case, then a stratigraphic continuity is suggested. Upper contacts of Cache Creek rocks are sufficiently rare to warrant critical re-evaluation of that exposed on Mount Patterson. Roots (1982, page 17) documents a similar contact relationship just 7 kilometres to the northeast.

STUHINI GROUP (uTRS)

Rocks of the "Stuhini Group" of Kerr (1948) are equivalent to those north of the British Columbia – Yukon border originally called the "Lewes River series" by Cockfield (*in* Lees, 1934) and later modified to "Lewes River Group" by Wheeler (1961). Five distinct lithologies are recognized as members of the Stuhini Group in the Tutshi Lake area; these are: variegated lapilli and ash tuffs with minor argillaceous wackes and limestones; cobble and boulder conglomerates; coarse pyroxene-porphyry pyroclastics; epiclastics overlain by hornblende-feldspar porphyry breccias and tuffs; and wackes, argillites and conglomerates enclosing a continuous limestone interval 20 to 150 metres thick. These lithologies are generally confined to the area east of the Llewellyn fault.

Composite thicknesses inferred from outcrop patterns vary from 0 to 3000 metres; Stuhini Group deposition probably onlapped metamorphic highlands and was variably eroded prior to Laberge Group deposition (*see* Figure 1-20-4). The lower age limit of the Stuhini Group is well constrained by an extensive macrofossil fauna within the underlying King Salmon Formation (Tulsequah map area; Souther, 1971) that yields a Karnian age. Sparse conodonts acquired from black argillites and carbonates near the top of the Stuhini Group (C. Dodds, personal communication, 1987) yield a Norian age (M. Orchard, personal communication, 1987).

VARIEGATED TUFFS AND SEDIMENTS (uTRSV)

This package of red, brown and grey-green feldspar± pyroxene-phyric lapilli tuffs locally gives way to immature sediments and thin (50-centimetre), unfossiliferous, marly limestone beds or pods (0.5 by 10 metres). The tuffs display pervasive chlorite alteration as well as patches of epidote up to 30 centimetres across. Lesser feldspar porphyry flows display similar alteration. Sediments are tan to black tuffaceous argillites in beds centimetres to decimetres thick. Where foliated, tuffs and sediments are carbonatized and display orange weathering. These tuffs and sediments are the most voluminous of Stuhini Group units within the map area and may acquire thicknesses of 2500 metres or more.

CONGLOMERATES (uTRSC)

Conglomerates are widely distributed within the Stuhini stratigraphy, occurring as mappable packages both within

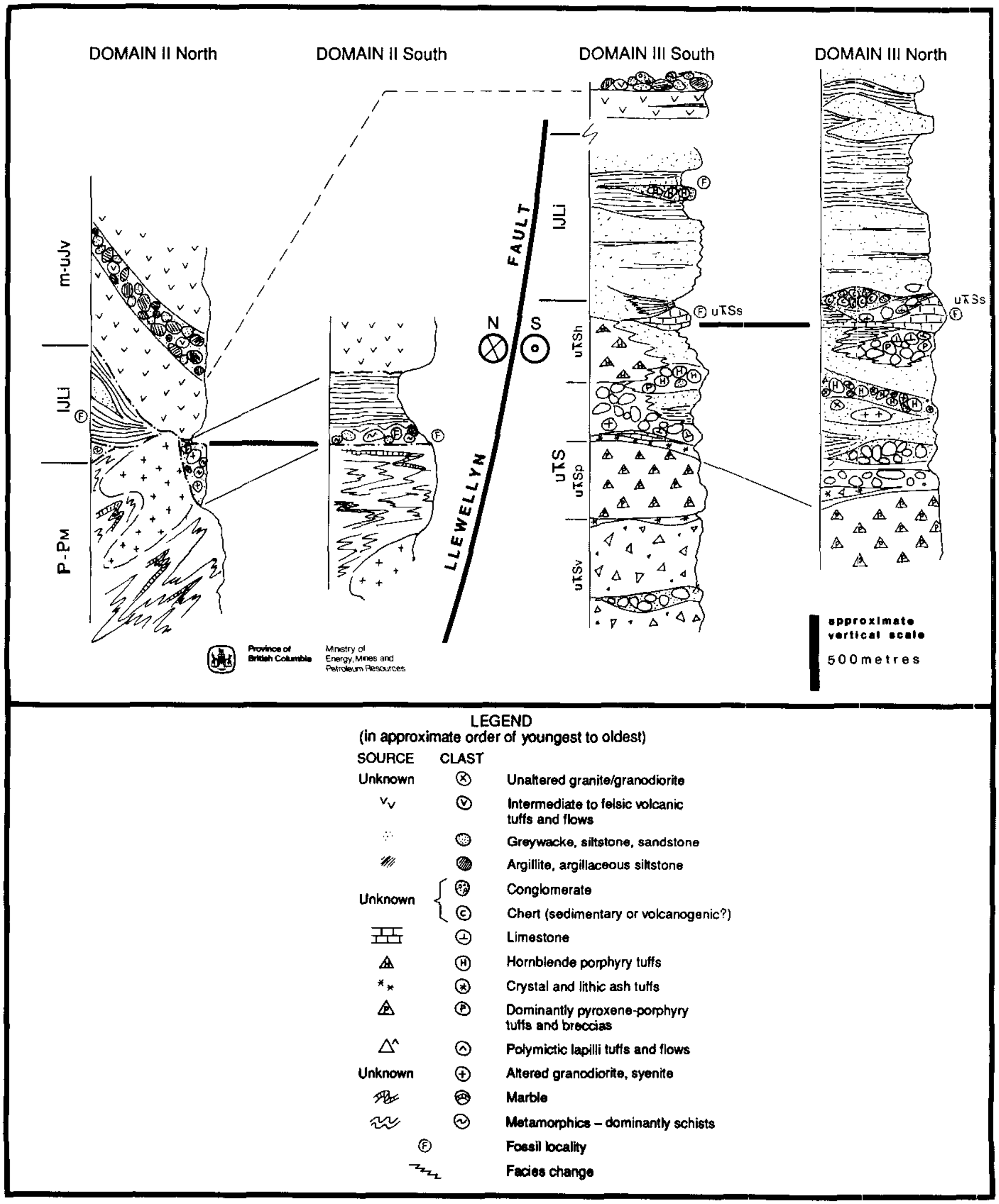


Figure 1-20-4. Stratigraphic correlation chart demonstrates the abrupt change in stratigraphy across the Llewellyn fault zone. Compiled from map outcrop patterns; thicknesses are not direct measurements. Only the Laberge Group of Domain II has both its upper and lower contacts exposed. Fold styles within the metamorphic rocks are diagrammatic, no vergence is implied.

Subunits uTRSv and uTRSh and above uTRSp and uTRSs, as groups of beds up to several hundred metres thick. Clasts are variable but generally dominated by either pyroxene or hornblende porphyries, altered granodiorite to syenite, or limestone. Other clasts include shale, fine-grained volcanic rocks, quartz and metamorphic rock granules. As more petrographic data are collected the presence and/or abundance of metamorphic clasts may be useful criteria in distinguishing Stuhini Group conglomerates from those of Laberge affiliation. Clast size is generally in the gravel to cobble range, but boulders up to 1 metre or more in diameter (particularly intrusive types) are present. These rocks are massive and thick bedded with coarse litharenite and wacke interbeds.

GREEN PYROXENE PORPHYRIES (uTRSp)

Dark green pyroxene porphyries typify the Stuhini Group within the map area and are at least 450 metres thick. They are normally massive, coarse, monolithologic lapilli tuffs and breccias containing roughly 20 per cent pyroxene (up to 1 centimetre in diameter) and 40 per cent plagioclase. Well-layered interbeds of maroon crystal and lithic ash tuffs are common (2 to 10+ metres thick). Petrographic analyses reveal chlorite and serpentinite pseudomorphically replacing rare olivine phenocrysts. Igneous textures are typically well preserved except near structural or intrusive contacts where extensive alteration of pyroxene by actinolite, chlorite and epidote, and of plagioclase by white micas and prehnite, may occur.

HORNBLENDE-PHRYIC TUFFS AND EPICLASTICS (uTRSh)

These rocks are seen in two localities, immediately west of the Venus mill site and southwest of Moon Lake (near showing No. 21 on Figure 1-20-3) forming wedge-shaped packages. Observed thickness varies up to approximately 1500 metres.

This unit is characterized by grey-green to mauve and tan, dense, angular, hornblende-feldspar-phyric, fragmental volcanic rocks. Penecontemporaneous conglomerates contain a large proportion of clasts derived from this lithology as well as hornblende granodiorite (up to 1 metre diameter), syenite, limestone and cherty rocks.

CARBONATE UNIT (uTRSs)

The carbonate forms a continuous belt that can be followed from south of Tutshi Lake to north of the British Columbia–Yukon border within Domain III (Figure 1-20-3). It was mapped by Bultman (1979) as Upper Triassic Sinwa Formation equivalent based on lithologic similarity, and a continuity of its outcrop trend to where better exposed within adjacent map areas (Whitehorse, Wheeler, 1961; Tulsequah, Souther, 1971). It is in part podiform, perhaps representing patch-reef deposition, and is locally offset by small faults oriented nearly normal to its contacts. The carbonates display a striking degree of internal deformation. Disharmonic folding is outlined by graphitic layers, while extensive calcite vein development, up to 2 centimetres thick, accompanies recrystallization. Irregular black cherty stringers are locally present. The lower contact is locally gradational with argillites of decreasing carbonate content, while the upper contact and in places the lower one, are in abrupt contact with limestone-cobble conglomerates and greywackes. Thickness varies from less than 20 metres to approximately 150 metres and appears to be structurally thickened to 350 metres on the south side of Tutshi Lake, however, original depositional thickening due to carbonate build-up cannot be ruled out.

Macrofossils within this unit are sparse although crinoid ossicles, poorly preserved bivalves, and corallites can be found. A possible extension of the carbonate, 7 kilometres south-southwest of Moon Lake, is a sizeable outcrop of limestone with no exposed contacts, containing well-preserved fossils including colonial corals. A sparse conodont fauna collected from near the Venus mill yielded a Norian age (M. Orchard, personal communication, 1987; collected by C. Dodds).

LOWER JURASSIC LABERGE GROUP, INKLIN FORMATION (lJLi)

Cairnes (1910) used the "Laberge Group" to denote conglomerates, greywackes and argillites in a southeast-trending belt of miogeoclinal rocks recognized by Souther (1971) as the deep water Inklin Formation and shallow water Takwahoni Formation of the Whitehorse trough. Inklin Formation rocks underlie much of the eastern part of the map area where they are intruded by granitoid stocks. Thickness is difficult to assess due to widespread folding and minor thrust faults. Thickness estimates for the Inklin Formation within 104M and adjacent map areas range up to 7000 metres (Table 1-20-2). Uninterrupted successions within the western Tutshi Lake map area only reach 630 metres, although the maximum thickness is probably much greater. This thickness diminishes westward to where the Laberge stratigraphy is missing and Middle to Upper Jurassic volcanics rest directly on the Boundary Ranges metamorphic rocks.

Typical Laberge Group lithologies include conglomerate, greywacke, diamictite, immature sandstone and siltstone and both noncalcareous and weakly calcareous argillite. Conglomerates and greywackes tend to form massive beds while

TABLE 1-20-2
TABLE OF FORMATION THICKNESSES FROM ADJACENT AREAS

Group or Formation	Bultman (1979)	Souther (1971)	Wheeler (1961)
Stuhini Group and Lewes R. Group	Division A — up to 800 m Division B — 900–2500 m Division C — 200–450 m	~3600 m atop basal conglomerate	1000+ m
Inklin Fm.	5000–7000 m	~3100 m	1600 m, Montana Mtn.

argillites and siltstones are normally thinly bedded and may be laminated. Conglomerates commonly occur as tabular or lensoid bodies reflecting channelized deposition. Rapid lateral facies changes within the Inklin Formation are well portrayed by Wheeler (1961, Figure 7).

The age of the Inklin Formation in the Tutshi Lake map area is constrained by the Norian age of the underlying carbonate unit described above, and by a fossil collection of probable Toarcian age (H. Tipper and T. Poulton, personal communications, 1987) containing ammonites, brachiopods and pelecypods from within Inklin strata. Ammonites of probable Toarcian age from central Domain IIIN are particularly significant as these strata were originally mapped as Upper Triassic Stuhini Group (Christie, 1957).

MIDDLE TO UPPER JURASSIC VOLCANICS (muJv)

The nomenclature of Mesozoic and Tertiary volcanic rocks in northern British Columbia and southern Yukon is currently in a state of flux. The names used in this report are subject to change as a more refined understanding emerges. The unfossiliferous nature of these dominantly subaerial volcanics underscores the necessity for systematic radiometric age dating to establish relationships between isolated volcanic packages.

Intermediate to felsic pyroclastics and intermediate to mafic flows are found coring synclines in Domain II, as a downfaulted block in Domain V, and as small isolated packages throughout Domain IIIN. Nowhere is a complete section observed, however, a continuous section near Pennington is at least 650 metres thick.

Typical lithologies include: dark grey-brown, bladed-feldspar porphyry flows 5 to 20 metres thick, with interflow lapilli tuffs of the same composition; maroon to green, well-bedded, angular felsic lapilli ash tuffs; massive dark green angular lapilli tuffs; rhyolite ash flows and rare lava flows (mainly in Domain V); maroon, grey and green feldsparphyric flows and coarse pyroclastics; interbeds of conglomerates derived primarily from underlying Inklin Formation strata; bladed-feldspar crystal ash tuff; and polymictic felsic lapilli tuffs.

These rocks are younger than the underlying Inklin Formation (Lower to early Middle Jurassic), and older than a crosscutting granite dyke in Domain II dated at 77.9 ± 1.6 Ma (Table 1-20-3; Bultman, 1979). A deformational event folds these strata, but does not affect the younger Montana Mountain volcanics or crosscutting granites.

MONTANA MOUNTAIN VOLCANICS (uKm)

Montana Mountain volcanics within the map area are so called because of their similarity with rocks of the adjacent Montana Mountain volcanic complex mapped by Roots (1982). The rocks have been previously mapped as "Volcanics of uncertain age" by Christie (1957), Hutshi Group by Wheeler (1961), and Sloko Group by Monger (1975). Roots considered the Montana Mountain complex equivalent in both character and age to better defined Mount Nansen Group rocks exposed in adjacent map areas to the north. Within 104M/15 Montana Mountain volcanics are restricted to the northeastern part of the map area. They are dominantly orange-buff weathering and poorly to nonwelded acid lapilli tuffs and rhyolite flows. Remnant feldspars and quartz phenocrysts are recognized in hand sample. Microscopic examination reveals glomeroporphyritic plagioclase (and sanidine ?), partly altered to calcite, chlorite, sericite and epidote, embayed quartz and rare muscovite.

TABLE 1-20-3
ISOTOPIC AGE DATA
(*See* Figure 1-20-1 for locations)

Source	Sample No.	Isotopes	Age (Ma)
Bultman, 1979	T75 101-4b	K-Ar/biotite	89.5 ± 2.6
Bultman, 1979	T75 102-2b	K-Ar/biotite	77.9 ± 1.6
Bultman, 1979	T75 413-1b	K-Ar/biotite	82.0 ± 2.1
Morrison *et al.*, 1979	WHA9	K-Ar/biotite	64.3 ± 2.2

INTRUSIVE ROCKS (uKg, gd, qm, d)

Intrusive rocks of Cretaceous and earliest Tertiary age are widespread throughout the map area, occurring as part of the main mass of the Coast Crystalline belt to the west (Domain I) or as satellite plutons and stocks to the east (Domains III and IV). Dykes are both temporally and compositionally diverse. The predominant rock type is coarse-grained hornblende biotite granite with perthitic, megacrystalline potassium feldspar. Variations to finer grain sizes are common and contacts are typically chilled for widths of over 30 centimetres to many metres, where they appear as quartz-eye porphyries. Due to the high level of intrusion, the country rocks are not extensively hornfelsed, although skarn development may occur within calcareous units tens of metres away from these contacts. Mariolitic cavities were seen at one locality along the eastern shore of Bennett Lake. As further evidence of the high level nature of these intrusive bodies, rapakivi textures exist in the Domain IV Jack Peak stock and Domain III quartz monzonites. These textures are common within intrusive bodies that have been emplaced very near the earth's surface and have associated felsic volcanic outpourings. Compositions vary from granodiorite and quartz monzonite to alkali granite. Garnet and muscovite are rare accessory phases visible in hand sample. Petrographic analyses indicate that sphene and apatite are common.

Two isotopic age dates are available from the plutonic suite within the map area, and two others from adjacent sheets to the north and southeast are shown in Table 1-20-3.

CONTACT RELATIONSHIPS

Contacts within the map area are complicated by extreme fold amplitudes and consequent shearing on fold limbs, and widespread, profound angular unconformities which are, in places, difficult to distinguish from juxtaposition by faulting.

Boundary Ranges Metamorphics: The base of the Boundary Ranges metamorphic suite was not recognized, although pyroxenite bodies in northern Domain II and/or metabasalts may represent the basement lithologies atop which the Boundary Ranges sedimentary and volcanic protoliths were deposited. This speculation requires further investigation.

The upper contact of the metamorphic package is well exposed in Domain II, particularly on the ridges north and west of Skelly Lake, where the Laberge Group rests upon it with angular unconformity. Here an overlying basal conglomerate contains rounded clasts of metacarbonate; strained quartz and muscovite schists typical of the underlying metamorphic suite; a matrix of coarse wacke of Inklin Formation affinity; and well-preserved belemnites (Plate 1-20-3).

Just east of Bennett Lake, "Middle to Upper Jurassic Volcanics" rest directly on altered granodiorites of the Boundary Ranges metamorphics, indicating that the Laberge and Stuhini Group strata have been eroded or were never deposited at this locality. Nearby, the top of the metamorphic suite is represented by a conglomerate more than 500 metres thick, almost exclusively containing clasts of underlying schists and altered granodiorite.

Stuhini Group: The contact between the Stuhini Group and the underlying metamorphic terrane is exposed north of Paddy Pass where it displays attributes of both a stratigraphic and a tectonic contact. At this locality fragmental pyroxene porphyry and sandstone fragments are separated from schists by a carbonate-cemented shear zone 20 centimetres wide. No penetrative fabric suggestive of a tectonic contact is developed within Stuhini Group strata adjacent to the shear; on the other hand, no metamorphic clasts are found within the overlying Stuhini Group.

The top of the Stuhini Group is not clearly marked. Rather, the contact appears gradational in as much as the general lithologies above and below the limestone member are for the most part indistinguishable. Nevertheless the contact must be near the top of the limestone marker as this unit is apparently correlative with Sinwa Formation limestone (Bultman, 1979) that occurs between the Stuhini and Laberge groups.

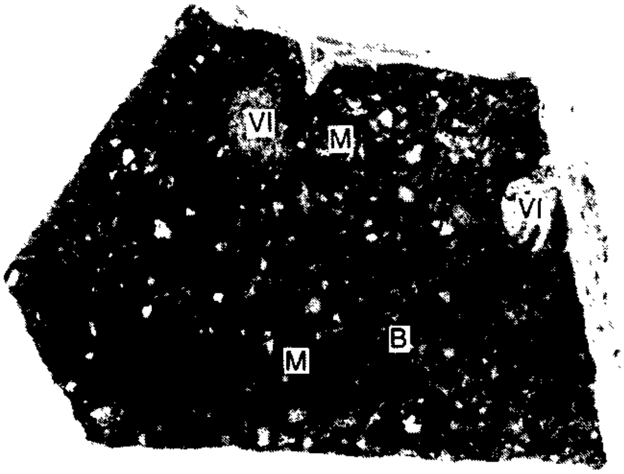


Plate 1-20-3. A conglomerate overlying Boundary Ranges metamorphics on the ridges north of Skelly Lake. Clasts derived from the underlying metamorphic rocks (M) are abundant within a lithic wacke matrix of Laberge Group affinity. Belemnites (B) are common at the locality from where the sample was taken. Clasts of fine-grained intrusive or volcanic origin (VI) are also present (Stuhini Group?).

Laberge Group: The upper contact of Laberge Group strata is exposed at several localities. One of the most continuously exposed contacts is near Pennington, where the contact is undulating and erosional, with olistostromal blocks of Inklin Formation argillites found within Middle to Upper Jurassic volcanic rocks. On the west side of southern Tutshi Lake, bladed-feldspar crystal tuffs, rhyolitic lapilli tuffites and pillow breccias (?) at the base of the Jurassic volcanics appear to have an argillaceous matrix. A thick conglomerate within the volcanic sequence is comprised partly of volcanic clasts, but predominantly of well bedded siltstones and argillites of the underlying Inklin sediments. It is suggested that the volcanics were deposited on an irregular, uplifted but partly submarine surface of Inklin Formation strata.

Contact relationships between the Nakina Formation and the Montana Mountain volcanics and the units described above are unknown in the Tutshi Lake area. However, rocks that are probably related to the Montana Mountain volcanics (Roots, 1982) are exposed in the Tagish Lake area, and appear to have been laid down upon an irregular surface of the Cache Creek Group (Monger, 1975).

STRUCTURE

The dominant structural trend within the map area is outlined by the surface traces of the Llewellyn fault zone (Figure 1-20-2) and major fold hinge surfaces, both oriented at 340 degrees. At this latitude the axis of the Whitehorse trough and bounding terranes are coincident with this trend.

Folds: Fold styles west of the Llewellyn fault are dominantly isoclinal to open and upright horizontal. To the east, horizontal to inclined-plunging folds are common, especially within Laberge Group strata (Plates 1-20-4, 1-20-5). Based upon dip isogons, folds are generally divergent (and chevron) to similar and typically have long limbs. Major folds within Laberge Group strata tend to decrease in amplitude and increase in wavelength toward the northeast, although minor tight folds superimposed upon their limbs are abundant. A strong axial planar foliation is developed within the hinges of tight folds. These axial surfaces are not folded except by late kinks produced by minor fault displacements. Minor warping of major folds has resulted from emplacement of intrusive bodies such as the Jack Peak stock.

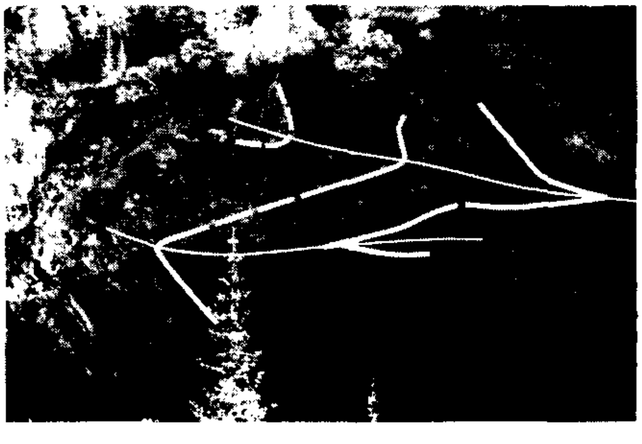


Plate 1-20-4. Open to tight, reclined chevron folds within Inklin Formation strata.

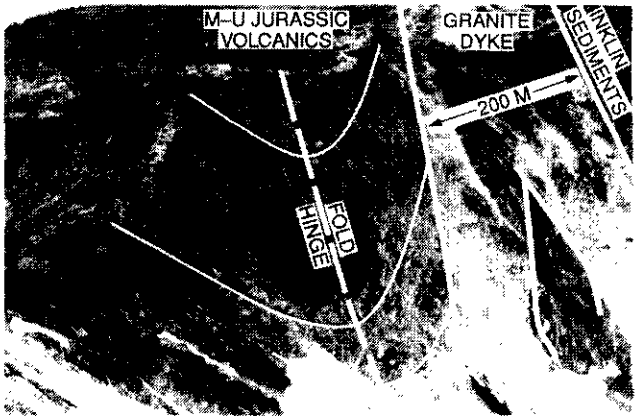


Plate 1-20-5. Close to open fold style within Middle to Upper Jurassic volcanics which overlie Lower Jurassic Inklin Formation rocks on the ridges east of southern Tutshi Lake.

Folding within the metamorphic basement appears to be dominantly coplanar and tight to isoclinal, similar and upright. Metamorphic rocks also display disharmonic folding and limbless or decapitated folds. Hingelines typically plunge less than 20 degrees both northerly and southerly. Vertical folds are not unknown, particularly within zones of disharmonic folding. Evidence for noncoplanar folding is seen in at least one sample where a crenulation cleavage strongly overprints the previous foliation. Curving hinge traces on the map do not necessarily represent a succeeding phase of folding, rather their formation is probably synchronous with formation of the dominant late fold trend.

The deformational history is difficult to ascertain due to the prevalent coplanar folds, the likelihood that prior structures have been transposed into their current configuration by shearing at 340 degrees azimuth, and the lack of continuous marker horizons. An earlier fabric oriented at 290 degrees is preserved in rare instances and is incipiently transposed to 340 degrees (Plate 1-20-1) probably by dominantly dextral shear. Multiple phases of veining, which are later crosscut, folded and rodded, point to a long and continuous deformational process.

Faults: Faults throughout the map area reflect the presence of tight, high amplitude folds with much interstratal slip, or proximity to the Llewellyn fault zone of Bultman (1979). The Llewellyn fault is a major structure that marks the eastern limit of Boundary Ranges metamorphic rocks and a westward change to much thinner Laberge Group strata. As such, it is clearly a feature of regional significance that represents a long-lived zone of structural weakness along which felsic bodies intruded and were later deformed to produce an anastamosing gouge network enclosing sheared, aligned, clay-altered and silicified lenses of intrusive rock (Plate 1-20-2). Latest motion predates felsic crosscutting dykes of the same suite which cut the Jack Peak stock and deformed Middle Jurassic volcanic strata. A west-side-up motion is superimposed on the dominantly transcurrent Llewellyn fault at its south end, in contrast to a east-side-up displacement at its northern end.

Other faults may be related to emplacement of intrusive bodies and do not necessarily conform to the regional trend. An inferred fault defining the southwest boundary of Domain V is thought to have mainly normal motion in juxtaposing Mississippian and Upper Cretaceous strata. Faults cutting intrusive rocks are brittle features represented by zones of shattered and clay-altered rock that are generally less than 2 metres wide.

Low-angle or bedding-parallel faults with demonstrable reverse motion were seldom observed within Inklin Formation strata. However, where exposed along the Klondike Highway at the south end of Tutshi Lake, these rocks are cut by closely spaced faults subparallel to bedding and trending 340 degrees. Motion along these faults is difficult to estimate but at the scale of mapping may be significant, and assuming a consistent reverse sense of motion, they are likely responsible for considerable thickening.

Motion on the Llewellyn fault zone may be partly linked to underthrusting on the King Salmon fault (Bultman, 1979) since the traces of these two fault systems merge near the southern end of Atlin Lake. However, the Llewellyn fault also appears to be involved in the formation of the western margin of the Whitehorse trough, as evidenced by the thinned Early to Middle Mesozoic strata to the west of the fault, and was probably active by Early Jurassic times. Late Early to early Middle Jurassic motion on the King Salmon fault (Thorstand and Gabrielse, 1986) must post-date initial motion on the Llewellyn fault. Displacement on the Llewellyn fault, if consistent with linkage on the King Salmon fault system, must necessarily be dominated by dextral transcurrent motion. Mesoscopic kinematic indicators are consistent with dextral motion but are not totally unambiguous (Plate 1-20-1; a microstructural analysis is currently underway). Subparallel fault zones are evident at many localities within Domain II; however, fault-related deformation appears to be concentrated in a zone several metres to tens of metres across (the Llewellyn fault). Two lines of evidence suggest that total displacement may be considerable: the change in apparent thickness of Laberge sediments from one side of the fault to the other, and the change in abundance of Stuhini Group rocks across the fault.

MINERALIZATION

Exploration within the map area dates back to 1897 when a major influx of prospectors bound for the Klondike goldfields passed the shores of Bennett Lake. Current interest is represented by the distribution of claims shown in Figure 1-20-3; staked ground is largely restricted to the rocks of Domain II. A brief description of each prospect is provided in Table 1-20-4. Host rocks range from Boundary Ranges metamorphics to Late Cretaceous intrusives.

Showings are of two major types: stibnite-bearing veins within dilatent zones with or without concomitant shearing, these also host galena, sphalerite and arsenopyrite; and sheared quartz-carbonate-altered zones within Triassic volcanics, these contain brecciated galena and sphalerite. Showings of more restricted occurrence are of several types: arsenopyrite and pyrite, with or without sphalerite, stibnite and galena, concordant with foliation in chlorite schists of the metamorphic suite; a small body containing angular carbonate fragments in a matrix of massive sphalerite and galena; and altered and sheared mafic volcanics (Stuhini ?)

TABLE 1-20-4
MINERAL OCCURRENCES — NTS 104M/15

No.	Name (MINFILE No.)	Commodity	Assay	Sample width	Description
			(reference)		
1	Bennett Lake (104M 032)	Limestone	NA	NA	Stratified recrystallized limestone within pre-Permian metasediments, local garnet-epidote skarn development.
2	Gridiron (104M 001)	Au	3.2 g/t	grab	Up to 1-metre-wide quartz veins within silicified and talcose fault zones of pre-Permian metamorphics; mineralization has developed along the contact of the Coast complex and the Nisling terrane.
		Ag	315 g/t	grab	
		Pb	2.0%	grab	
		As	1.3%	grab	
		Sb	NA	NA	
		Zn	NA	NA	
			(AR 10425)		
3	Gaug 1 (104M 040)	Ag	93.9 g/t	grab	Disseminated to massive copper-magnetite mineralization concentrated along a 4-metre-wide shear zone within Triassic (?) altered granodiorite.
		Cu	9.5%	grab	
		Fe	NA	NA	
			(AR 11044)		
4	Gaug 2 (104M 039)	Au	1.20 g/t	grab	East-trending shear zone bearing stibnite-arsenopyrite-pyrite-chalcopyrite-sphalerite-galena-rich quartz veins within altered Triassic (?) granodiorite.
		Ag	53.8 g/t	grab	
		Cu	0.71%	grab	
		Sb	0.28%	grab	
		Zn	NA	NA	
		Pb	NA	NA	
			(AR 11044)		
5	Silver Queen-North, Gaug-west (104M 038)	Au	15.9 g/t	1.0m chip	Disseminated to massive stibnite-galena-bearing quartz veins hosted within a 2-metre-wide fracture-controlled zone cutting the border phase of the Coast complex near its contact with Jurassic volcanics.
		Ag	394 g/t	1.0m chip	
		Pb	NA	NA	
		Zn	NA	NA	
		Cu	NA	NA	
		Sb	NA	NA	
			(AR 12554)		
6	Bald Peak, Gaug-South (104M 028)	Au	8.0 g/t	70cm chip	Silicified shear zone within rhyolites of Jurassic age contains mineralized quartz veins up to 70 centimetres wide.
		Ag	212 g/t	70cm chip	
		As	4.8%	70cm chip	
			(AR 11044)		
7	Silver Queen, Net (104M 002)	Ag	NA	NA	Pyrite, chalcopyrite and malachite staining occur along the contact between pre-Permian metamorphics and the Coast complex.
		Cu	NA	NA	
8	Ben Pond (104M 041)	Ag	90.6 g/t	3.3 m chip	A 3-4-metre-wide, disseminated to massive stibnite-galena-sphalerite occurrence follows the northwest-trending fault contact between pre-Permian metamorphics and Jurassic Laberge Group argillites.
		Pb	1.50%	3.3 m chip	
		Sb	1.30%	3.3 m chip	
		Zn	NA	NA	
			(AR 12554)		
9	Ben-Glacier (104M 043)	Au	6.60 g/t	grab	A 2-centimetre-wide fracture cutting Jurassic Laberge Group greywackes contains a primary cobalt mineral, erythrite staining and pyrite.
		Ag	1.70 g/t	grab	
		Co	0.37%	grab	
			(AR 12554)		
10	Ben-Camp (104M 042)	Au	12.5 g/t	grab	An irregular, discontinuous quartz vein appears to follow the pre-Permian metamorphic/Jurassic Laberge Group argillite contact.
		Ag	2136 g/t	grab	
		Pb	—	—	
		Zn	—	—	
			(AR 12554)		
11	Ben Creek (104M 003)	Au	0.32 g/t	1.0 m chip	A 1-metre-wide zone of sulphide mineralization parallels foliation in pre-Permian metamorphics.
		Ag	108 g/t	1.0 m chip	
		Pb	—	—	
		Zn	—	—	
		Sb	—	—	
			(AR 12554)		
12	Paddy (104M 044)	Au	3.7 g/t	grab	A narrow mineralized quartz vein occurs just southwest of a northwest-trending fault contact between pre-Permian schists and Upper Triassic Stuhini Group volcanics.
		Ag	338 g/t	grab	
		Pb	2.3%	grab	
		Cu	—	—	
		Zn	—	—	
			(AR 12554)		
13	Ben-Four (104M 047)	Au	22.7 g/t	grab	A 30 to 50-centimetre quartz vein is hosted within pre-Permian metamorphics.
		Ag	8.0 g/t	grab	
			(AR 12554)		
14	Ben-Northwest (104M 045)	Au	13.4 g/t	grab	Arsenopyrite-rich quartz veins up to 30 centimetres wide occur within three parallel shear zones in Upper Triassic Stuhini Group volcanics.
		Ag	1.20 g/t	grab	
			(AR 12554)		

TABLE 1-20-4—*Continued*
MINERAL OCCURRENCES — NTS 104M/15

No.	Name (MINFILE No.)	Commodity	Assay (reference)	Sample width	Description
15	Ben-Southeast (104M 046)	Au	0.10 g/t	grab	Galena-chalcopyrite-rich vuggy quartz veins up to 30 centimetres wide occur in Upper Triassic Stuhini Group volcaniclastic breccias.
		Ag	253.7 g/t	grab	
		Pb	1.40%	grab	
		Cu	—	—	
			(AR 12554)		
16	Unknown	mag	NA	NA	A 1.5-metre-wide northwest-trending fault-controlled magnetite-rich zone is exposed by trenches in Upper Triassic Stuhini Group pyroxene porphyries.
		Cu	NA	NA	
17	Unkown	NA	NA	NA	An adit follows a 1.5-metre-wide silicified shear zone trending northwest and containing 2–3% disseminated pyrite and chalcopyrite within Upper Triassic Stuhini Group sediments.
18	Pud	NA	NA	NA	Near its contact with Mid-Jurassic Laberge Group argillaceous shales, pre-Late Cretaceous Mount Nansen Group volcanics host a 1-metre-wide discontinuous quartz vein within a clay-altered shear zone.
19	Nasty Cirque	Au	78 g/t	grab	Localized 3 by 4-metre high-grade galena-sphalerite mineralization of enigmatic origin.
		Ag	617 g/t	grab	
		Pb	NA	NA	
		Zn	NA	NA	
			(AR 15500)		
20	Jessie, Big Thing (104M 027)	Au	5.2 g/t	1.5 m chip	A 1.8-metre-wide northwesterly trending shear zone occurs in pre-Permian metamorphics at the eastern contact of the Coast Complex.
		Ag	809 g/t	1.5 m chip	
		Cu	4.9%	1.5 m chip	
		Pb	NA	NA	
		Zn	NA	NA	
			(EMPR AR 1929, Pg 120)		
21	Moon Lake (104M 057)	Au	6.4 g/t	grab	Disseminated arsenopyrite-pyrite-galena-chalcopyrite-sphalerite mineralization is hosted in quartz-carbonate-altered Upper Triassic Stuhini Group pyroxene porphyries, tuffs and breccias.
		Ag	490 g/t	grab	
		Cu	4.0%	grab	
		Pb	1.4%	grab	
		Zn	0.3%	grab	
		As	1.4%	grab	
			(AR 15500; EMPR-Schroeter, 1986)		
22	Shelly (104M 052)	Cu	NA	NA	Small skarn zones within pre-Permian metamorphics display minor disseminated pyrite-chalcopyrite-galena; mineralization develops near the metamorphic/Coast intrusive contact.
		Pb	NA	NA	

NA = not available.

hosting disseminated pyrite and chalcopyrite within the Llewellyn fault zone. For a review of showings between Venus mine and the Engineer mine *see* Schroeter, 1986.

Stibnite-bearing Veins: These veins are widespread on the Ben and Gaug claim blocks. They occur within altered pre-Triassic felsic intrusives (Table 1-20-4, No. 4); at the sheared contact between Boundary Ranges metamorphics and Laberge Group argillites (Table 1-20-4, Nos. 8, 10, 12); and within the chilled margin (quartz-eye porphyry) of the granitic Coast intrusions (Table 1-20-4, No. 5). At the first four occurrences, veins typically have sheared walls, as exposed by trenches over strike-lengths of up to 4 metres. Occurrence 5 is a vein system continuous over at least 15 metres and striking parallel to the prevalent joint direction of 065 degrees.

If all stibnite-bearing veins represent the same mineralizing event then they must all post-date the Upper Cretaceous granitic host of occurrence 5 and are thus likely related to the late-stage, low-temperature thermal aureole associated with Upper Cretaceous intrusions.

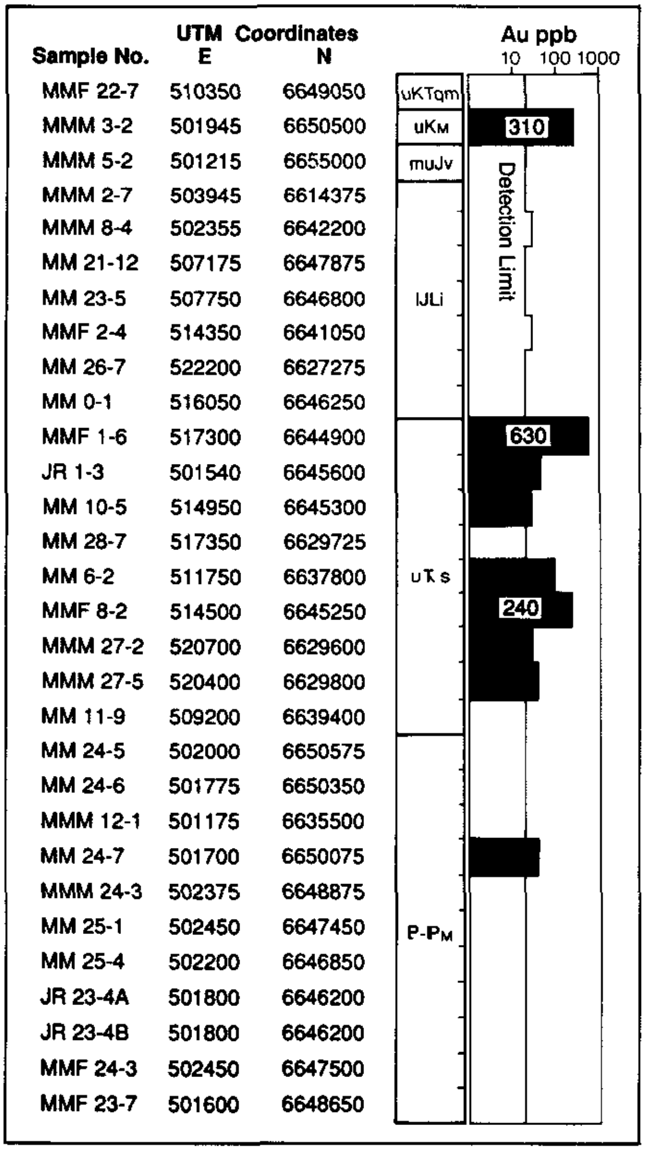
Quartz-carbonate Alteration: An orange-weathering quartz-carbonate-altered shear zone within Stuhini volcanics was the most active prospect within the map area in 1987 (Table 1-20-4, No. 21). The main mineralized zone measures approximately 100 by 300 metres with similarly altered but weakly mineralized or barren rocks occurring within a belt having a strike length of at least 2.5 kilometres. The mineralization is brecciated and sheared parallel to the regional trend and lies immediately adjacent to the Llewellyn fault. Galena and sphalerite locally comprise up to 25 per cent of the rock and weather out from the carbonate-rich matrix. Best available assays to date are 6.4 grams per tonne gold and 490 grams per tonne silver. The alteration and structural setting of this prospect are analogous to that of the Polaris Taku mine to the south (Tulsequah map area; produced from 1937 to 1951). A MINFILE survey of 104M and 104K shows that in over 50 per cent of the prospects where data are available mineralization is associated with shear zones.

Within 104M/15 preliminary analytical results from shears and veins (Figure 1-20-5) indicate that Stuhini Group volcanics have anomalous background gold values with respect to most other rock types in the area. It is not known whether this is a function of the primary abundance of gold in Stuhini Group rocks or the suitability of these rocks as a locus for auriferous mineral deposition. In light of the fact that most prospects within 104M and 104K are shear related, and past producing mines such as the Polaris Taku have this same structural setting, major fault zones within Stuhini Group rocks are likely exploration targets.

Polymetallic Sulphide Replacement Zones found within the Boundary Ranges metamorphic suite are subparallel with foliation (Table 1-20-4, No. 11) or, in one instance, form a subvertical discordant body of carbonate breccia with massive sulphide matrix (Table 1-20-4, No. 19). The ability to trace the continuation of such bodies within the metamorphic rocks is largely contingent upon accurately interpreting structures and calculating the direction and amount of displacement on minor faults.

Sheared Basic Volcanics: A grab sample of sheared basic volcanics (Stuhini ?) crosscut by hypabyssal dioritic intrusives, collected from where the Klondike Highway crosses the trace of the Llewellyn fault, contained minor disseminated pyrite, chalcopyrite and chalcocite and assayed 100 ppb gold.

Late and extensive vein systems, such as those at the Venus and Engineer mines, are mesothermal fissure-filling veins within Montana Mountain volcanics and Inklin Formation respectively. Evidence of shearing along vein margins is abundant in the Venus mine, while at the Engineer, pay veins tend to occur along splays of the Llewellyn fault. Clearly these faults are important conduits for the upward movement of mineralizing solutions. Similar faults occur throughout the Tutshi Lake area, due to the convergence of tectonic elements and a complex geologic history. Understanding the relationship between tectonic activity and mineral deposit genesis is one of the objectives of this continuing study.



Sample No.	UTM Coordinates E	N
MMF 22-7	510350	6649050
MMM 3-2	501945	6650500
MMM 5-2	501215	6655000
MMM 2-7	503945	6614375
MMM 8-4	502355	6642200
MM 21-12	507175	6647875
MM 23-5	507750	6646800
MMF 2-4	514350	6641050
MM 26-7	522200	6627275
MM 0-1	516050	6646250
MMF 1-6	517300	6644900
JR 1-3	501540	6645600
MM 10-5	514950	6645300
MM 28-7	517350	6629725
MM 6-2	511750	6637800
MMF 8-2	514500	6645250
MMM 27-2	520700	6629600
MMM 27-5	520400	6629800
MM 11-9	509200	6639400
MM 24-5	502000	6650575
MM 24-6	501775	6650350
MMM 12-1	501175	6635500
MM 24-7	501700	6650075
MMM 24-3	502375	6648875
MM 25-1	502450	6647450
MM 25-4	502200	6646850
JR 23-4A	501800	6646200
JR 23-4B	501800	6646200
MMF 24-3	502450	6647500
MMF 23-7	501600	6648650

Figure 1-20-5. Histogram of gold analyses as a function of stratigraphic position. Sample MMM 3-2 is from a MINFILE occurrence (Pud claims, No. 18 on Figure 1-20-3).

SUMMARY

New fossil data indicate that the Jurassic Inklin Formation is more widespread within the map area than was previously recognized. In the west-central map area these strata appear to be deposited on pre-Permian metamorphic "basement" termed the "Boundary Ranges metamorphics". A major fault zone, considered the extension of the Llewellyn fault of Bultman (1979), bisects the map area and is parallel to the dominant structural trend of 340 degrees. This fault marks the eastward extent of the Boundary Ranges metamorphics and a significant change in the thickness of Mesozoic strata, suggesting considerable fault displacement.

Latest folding post-dated a probable Middle to Upper Jurassic volcanic package and pre-dates the Montana Mountain complex of pre-Late Cretaceous age.

Although data are preliminary, analytical results from veins, shears and mineralized zones within Stuhini Group strata yield background gold values that are anomalous with respect to other map units within the study area. Also, many of the past gold producers within the same physiographic belt in northernmost British Columbia are associated with fault structures. Clearly Stuhini volcanics adjacent to the Llewellyn fault zone are an attractive mineral exploration target, but the potential of other lithologies as hosts to economic mineralization in this structural environment should not be ignored.

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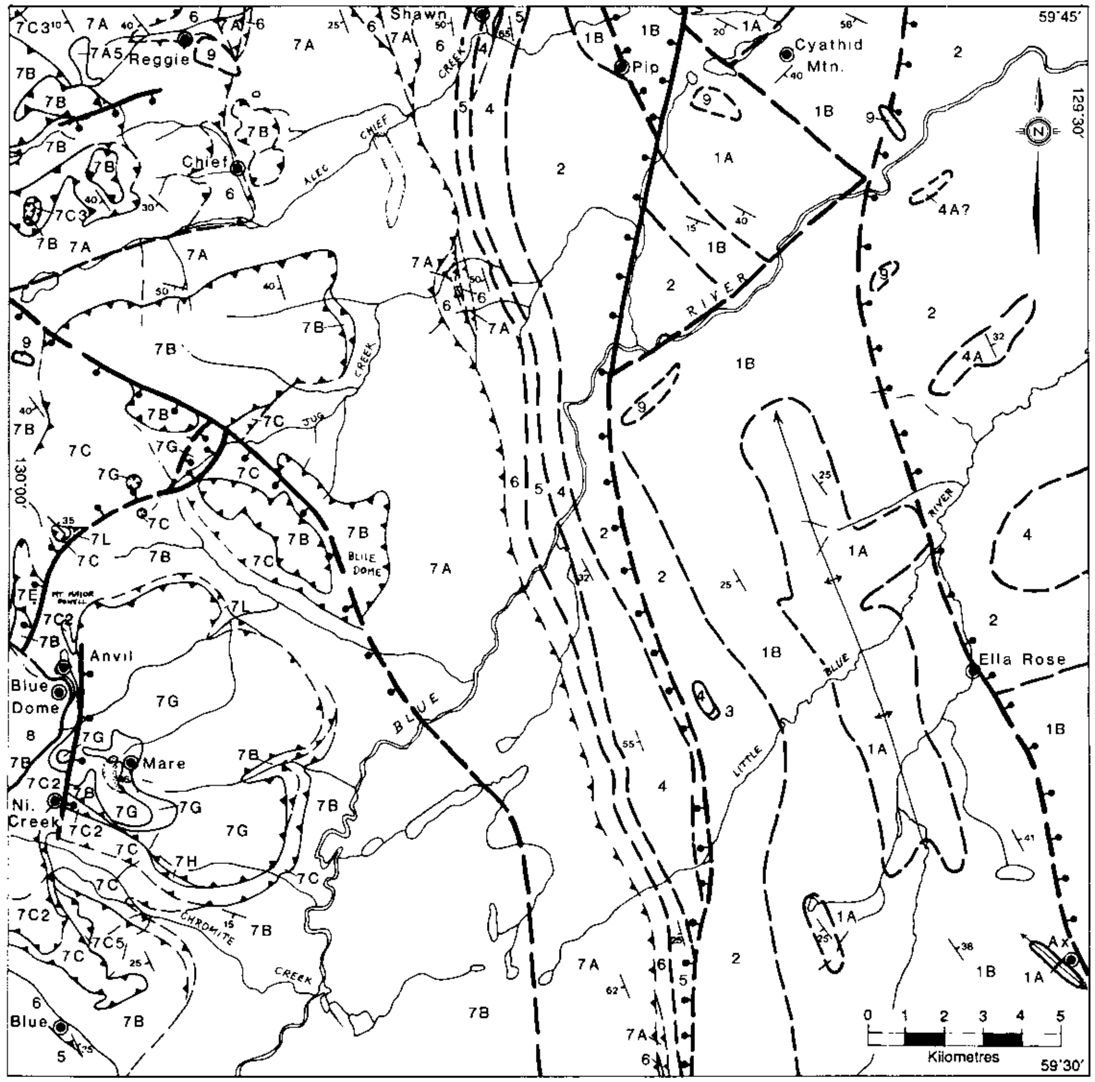

LEGEND

Miocene-Pliocene

9	Tuya volcanics: olivine basalt

Cretaceous

8	Cassiar batholith: granite, granodiorite

Devonian to Triassic

7	Sylvester allochthon

For complete list of Sylvester units, see Table 1

Division I

7A	Chert, argillite, limestone
$7A_5$	Greywacke, argillite, chert, exhalite

Division II

7B	Basalt, diabase, chert, argillite, diorite, gabbro
7C	Serpentinite and structurally related units
$7C_2$	Blue River ultramafite
7L	Triassic limestone

Division III

7G	Permian basic, intermediate, felsic volcanic rocks; limestone
$7G_2$	Calc-arenite, chert, limestone
7H	Permian limestone

Devonian-Mississippian

6	Earn Group: argillite, siltstone, greywacke, limestone, exhalites

Middle Devonian

5	McDame Group: dolomite, limestone

Lower Devonian

4	Tapioca sandstone: dolomitic quartz arenite, quartzite, dolomite

Ordovician to Lower Devonian

4A	**Sandpile Group: dolomite, dolomitic quartz arenite, limestone; fossilferous dolomitic siltstone and dolomite**

Ordovician-Silurian

3	Road River Group: black slate

Cambrian-Ordovician

2	**Kechika Group: thin-bedded limy slate, siltstone, limestone**

Lower Cambrian

Atan Group

1B	Rosella Formation: limestone, dolomite, grey and red shale
1A	**Boya Formation: quartzite, slate, siltstone, red shale**
◉	pervasive hydrothermal alteration

Figure 1-21-2. Geology and mineral occurrences, 104P/12.