Terrace Regional Mapping Project, Year 4: Extension of Paleozoic Volcanic Belt and Indicators of Volcanogenic Massive Sulphide–style Mineralization near Kitimat, British Columbia (NTS 103I/02, 07)

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KEYWORDS: Terrace, Kitimat, Stikinia, regional geology, VMS, Paleozoic, Telkwa, Coast Mountains, Skeena River

INTRODUCTION

This paper reports on results from the fourth and final year of the Terrace regional mapping and mineral potential evaluation project. Mapping in the vicinity of Williams and Chist creeks in 2007 led to the discovery of previously unrecognized Paleozoic volcanic rocks, the Mt. Attree volcanic complex, which contains broad zones of syngenetic alteration (quartz-sericite schist) and local occurrences of volcanogenic sulphides (McKeown et al., 2008; Nelson et al., 2008a). Given the northeast-trending structural grain of the area, it seemed possible that both the Paleozoic hosts and the belt of volcanogenic massive sulphide–related mineralization could extend beneath the glacial deposits of the Terrace-Kitimat valley and into the eastern Coast Mountains. Thus, it was decided to conclude the project with reconnaissance mapping in this area, focused on metavolcanic units identified in earlier regional coverage (Woodsworth et al., 1985; Heah, 1991).

Geological mapping in July and August of 2008 covered the Terrace-Kitimat valley between the Skeena River and Kitimat, and adjacent mountainous areas and the Skeena River valley to the west. Lowland traverses were done by truck and by foot; in general, logging operations in these areas date from the 1970s through to the early 1990s, and roads are reverting to dense linear stands of small alders. An A-Star helicopter was used to access the more remote ridges; from a base at the Terrace airport typical setout times were around 25 minutes round trip.

The most important new geological and exploration-related observations include

- the Paleozoic metavolcanic unit and its stratigraphically overlying, discontinuous Lower Permian limestone both extend west and southwest into the Coast Mountains in the core of a broad, regional, northeast-trending anticline;
- the anticlinal structure predates northwest-striking, northeast-side-down normal faults such as the Shames River and Amesbury Creek faults, which in turn are truncated by more northerly faults of the Kitsumkalum-Kitimat graben (Figure 2);
- the three base-metal sulphide mineral showings northwest of Kitimat show characteristics of volcanogenic massive sulphide (VMS) feeder zone systems; one contains abundant barite (Billy Barite, MINFILE 103I 217; MINFILE, 2008), and all have associated prekinematic quartz-sericite alteration; and
- the local northeasterly foliation-parallel orientations of these zones, as well as the continuity of trend with the Gazelle mineralization identified in 2007, which suggest that they form a single belt of VMS-style mineralization, probably controlled by a penecontemporaneous seafloor structure.

PREVIOUS WORK

The area covered in 2008 was previously mapped at 1:125 000 scale by Woodsworth et al. (1985). The Skeena River valley west of Terrace was mapped at 1:50 000 scale in the course of M.Sc. thesis work by Heah (1991). Assessment report mapping at 1:20 000 scale by Belik (1987) in the Paleozoic belt northwest of Kitimat was of great aid in locating overgrown showings and key outcrops.

GEOLOGY

Overview

The Terrace-Kitimat area lies within the central western Stikine terrane (Wheeler et al., 1991), which consists of superimposed island arc buildups of mid-Paleozoic through mid-Jurassic age, overlain by postcollisional clastic strata of the Bowser Basin. Regional geology of the area, compiled from 1:20 000 scale mapping in 2005–2008, shows Paleozoic to Lower Jurassic volcanic and related units intruded by the Early Jurassic Kleanza pluton, all of them overlain to the north and east by the mid-Jurassic Smithers Formation and Troy Ridge facies, and Upper Jurassic and younger Bowser siliciclastic units (Figure 2). The southern margin of the Bowser Basin is defined by the Skeena arch, which formed a topographic high in Jurassic–Cretaceous time and shed detritus northwards into the basin (Tipper and Richards, 1976; Nelson and Kennedy, 2007). Abundant Cretaceous and younger plutons in the area represent the eastern part of the Coast Plutonic Complex.

In the mountains southeast of Terrace, volcanic, volcaniclastic and overlying carbonate strata of the Permian and older Zymoetz Group are overlain by extensive exposures of the Early Jurassic Telkwa Formation (Figure 2). The sequence is deformed into a broad, regional northeasterly anticline cored by the pre-Permian Mt. Attree volcanic complex. This regional structural culmination plunges to

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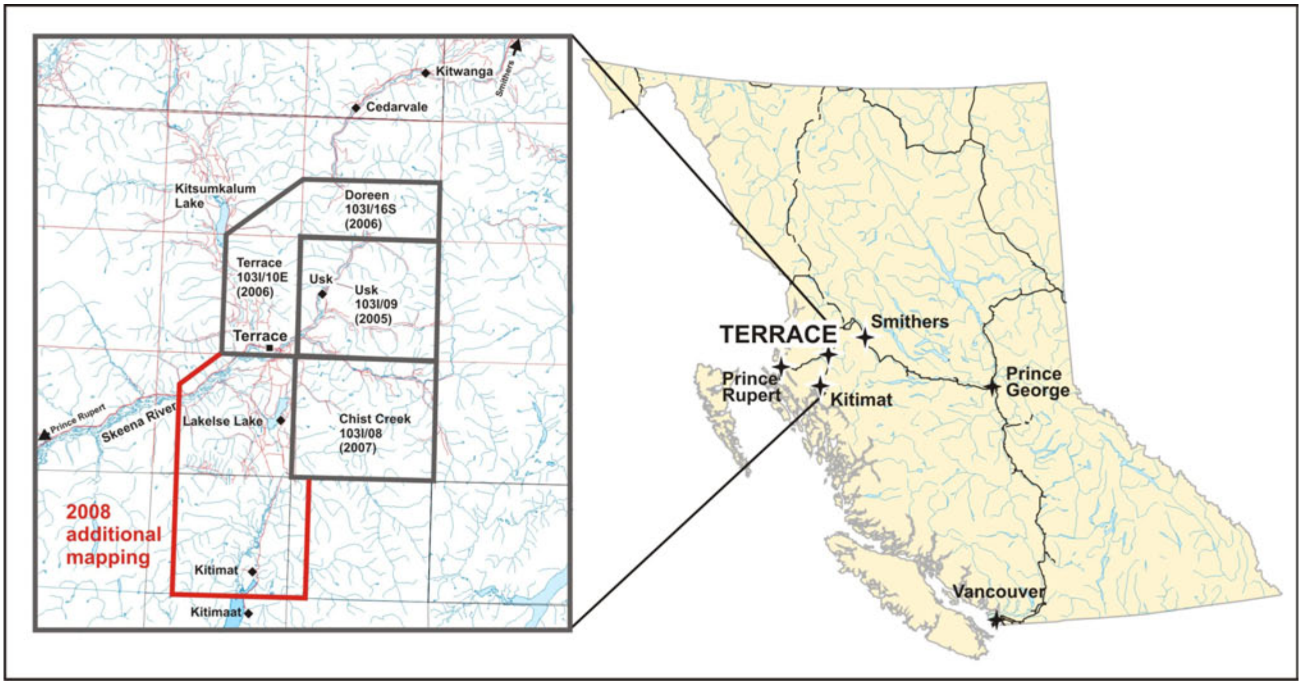


Figure 1. Location of 2005–2008 geological mapping near Terrace, BC.

the northeast; thus the deepest structural levels are exposed on peaks that flank the deep valley between Terrace and Kitimat (Angen, 2009). The valley itself is occupied by a complex graben structure, the Kitsumkalum-Kitimat graben (Figure 2). Farther west, pre-Permian volcanic units are found on the eastern slopes of Mt. Clague near Kitimat and on Nash Ridge west of the Terrace airport. These western Paleozoic volcanic rocks are dominated by opaline quartz-phyric dacite and fine-grained greenstone; they are unlike the andesite-dominated, plagioclase- and clinopyroxene-phyric volcanic sequences near Williams and Chist creeks. It is likely that they were the products of separate but coeval volcanic centres.

Stratified Units

ZYMOETZ GROUP

The name Zymoetz Group was proposed by Nelson el al. (2006a) for a section of Paleozoic volcanogenic and marine sedimentary strata overlain by Permian limestone, which outcrops between the lower Zymoetz River valley northeast of Terrace and the lower reaches of Chist Creek. The Zymoetz Group is divided into two units: a lower, volcanogenic unit, the Mt. Attree volcanic complex, overlain by Lower Permian limestone that is age equivalent to, and correlative with, the Ambition Formation of Gunning et al. (1994). In 2008, both of these units were traced west and south across the broad glacial valley between Terrace and Kitimat, to exposures along the Skeena River and south into the eastern Coast Mountains (Figures 2, 3).

Mt. Attree Volcanic Complex

This unit was named for Mt. Attree, a prominent summit on the ridge between the Zymoetz River and Williams Creek (Nelson et al., 2008a). The dominant composition on the ridge is andesitic, as flows and pyroclastic and epiclastic beds. Farther south from the height of land between Williams and Chist Creek, it also contains rhyolite and dacite and a thin interval of volcanic-derived sedimentary strata.

Greenschist-facies metavolcanic rocks probably equivalent to the previously defined Mt. Attree volcanic complex occur near the Skeena River west of Terrace, extending southwards onto Nash Ridge, near the Wedeene River and on Mt. Clague near Kitimat (Figure 3). Typically in these exposures, opaline quartz-phyric dacite (Figure 4a, b) is interlayered with metabasaltic (?) greenstone. The dacite represents both tuff (Figure 4a) and related high-level porphyritic intrusions (Figure 4b). In some instances, well-preserved primary volcaniclastic textures allow identification of pyroclastic andesite and rhyolite-dacite breccia (Figure 4c). More commonly, the quartz-phyric dacite appears as chlorite-actinolite schist with round relict quartz phenocrysts. Pyritic quartz-sericite schist occurs on Nash Ridge and near Bowbyes Lake north of Kitimat.

The dating of these rocks as Paleozoic is based on preliminary evidence. They lie on structural trend with the Mt. Attree volcanic complex as previously defined; they share characteristic lithological features, metamorphic grade and northeasterly structural orientations. Heah (1991) reported a ca. 331–317 Ma U-Pb age from metatonalite within the unit north of the Skeena River, and there are unpublished U-Pb data indicating possible Mississippian age from northwest of Kitimat (G. Woodsworth, pers comm, January 2008). Several samples were collected this year for new U-Pb dating.

Ambition Formation

Fossiliferous Permian limestone outcrops in an east-striking belt between the Old Remo Road and the Skeena River. Farther south near Lakelse Lake, marble forms part of several roof pendants less than 1 km in scale. It is correlated with the Ambition Formation as defined locally (Nelson et al., 2008a). Its stratigraphic context is seen clearly along a logging cut west of Mt. Herman, where it is overlain by a sequence typical of the Triassic sedimentary unit and Jurassic Telkwa volcaniclastic rocks. Ovoid, centimetre-scale wollastonite patches in the marble resemble chert blobs in unmetamorphosed Permian limestone east of Mt. Remo.

On the lower slopes of the mountain east of Shames River, well-bedded, pure to impure, siliceous marble intervenes between Paleozoic, mainly intrusive rocks and the Telkwa Formation (Heah, 1991). This is also regarded as correlative with the Ambition Formation.

Duffell and Souther (1964) showed a broad, kilometre-scale band of marble on the western side of Fire Mountain northeast of Kitimat. In traversing this area, we found only a very small marble pod apparently surrounded by diorite and gabbro. Nearby chlorite schist and greenstone are correlated with the Mt. Attree volcanic complex.

TRIASSIC SEDIMENTARY STRATA

A thin unit of dark, thin-bedded, fine-grained sedimentary strata occurs between the Permian limestone and overlying andesitic volcaniclastic rocks at two localities within the valley south of Terrace, one along a logging spur west of Mt. Herman and another on a low hill east of Old Remo (Figure 2). The Mt. Herman locality is part of a roof pendant surrounded by diorite and gabbro of probable Early Jurassic age. Northeast-striking, thick-bedded pure marble is overlain on a sharp contact by 200 m of thin-bedded black siliceous hornfels. The beds are pyritic and coated with rusty iron-oxide weathering products. Their protoliths included chert, siliceous siltstone and lesser calcareous siltstone. They are overlain on a sharp contact by green tuff of the basal Jurassic Telkwa Formation. Although no fossils were found at this locality, the sequence of limestone, thin-bedded dark sedimentary strata and green volcaniclastic beds is identical to well-exposed and well-dated sequences along the Zymoetz River (Nelson et al., 2008a). As is the case there, the chert-argillite unit represents a thin, basinal Triassic facies that contrasts strongly with thick volcanic sequences in the Stuhini Group farther north and east within the Stikine terrane.

The Old Remo locality has been described previously by Mihalynuk (1987). It is atypical of the Triassic section seen elsewhere near Terrace. A small quarry pit near Kozar Road exposes monolithologic basalt breccia with entrained irregular, contorted inclusions of thin-bedded, black siliceous and calcareous argillite (Figure 5a, b). The basalt breccia is generally finely comminuted, with most clasts in the centimetre range. Basalt clasts within it contain well-formed, abundant augite phenocrysts in a glassy matrix. Both matrix and clasts are flooded by carbonate. The sedimentary inclusions range in size from subcentimetre wisps to decimetre blocks. The large inclusions are chaotically folded (Figure 5a). Their margins are irregular and wavy, with fine-scale penetration of the basalt matrix into laminated argillite (Figure 5b). As noted by Mihalynuk (1987), the textures at this outcrop are consistent with volcanism in a marine environment, incorporating wet, unlithified sediment into a pyroclastic breccia. The strong carbonate alteration of the basalt and the wispy basalt-sediment contacts are typical of peperite texture.

The depositional relationship between Triassic basalt and sedimentary strata at the Old Remo pit is unique within the Terrace area. In every other exposure, the Triassic unit contains no volcanic material, and is overlain unconformably by basal conglomerate and andesite breccia of the Telkwa Formation (Nelson et al., 2006a, 2008). North of the Zymoetz River, angular chert clasts in the conglomerate record incorporation after lithification (Figure 5c). Moreover, the basal unconformity of the Telkwa Formation cuts through the Triassic unit, across the Permian limestone and down into the upper part of the Mt. Attree volcanic complex (Nelson et al., 2008a). Therefore, it is most likely that the basalt east of Old Remo represents a unique occurrence within the Triassic section, rather than a precursor of Telkwa volcanism.

TELKWA FORMATION (HAZELTON GROUP)

The Lower Jurassic Telkwa Formation is exposed in several localities in the valley south of Terrace (Figure 3). On the logging spur west of Mt. Herman, basal Telkwa beds are mainly fine-grained green tuff and tuffaceous greywacke, with a few instances of andesitic lapilli tuff. On hills and in roadcuts southeast of Old Remo, coherent dacite and dacite breccia occur. They differ from Paleozoic dacite in that they have aphyric to small plagioclase-phyric texture, identical to those in the main Telkwa exposures farther east (Figure 6). They do not contain quartz eyes, nor are they associated with greenstone. They are similar to Telkwa dacite exposed along Highway 17 at the southern end of Kitsumkalum Mountain and on the west bank of the Zymagotitz River.

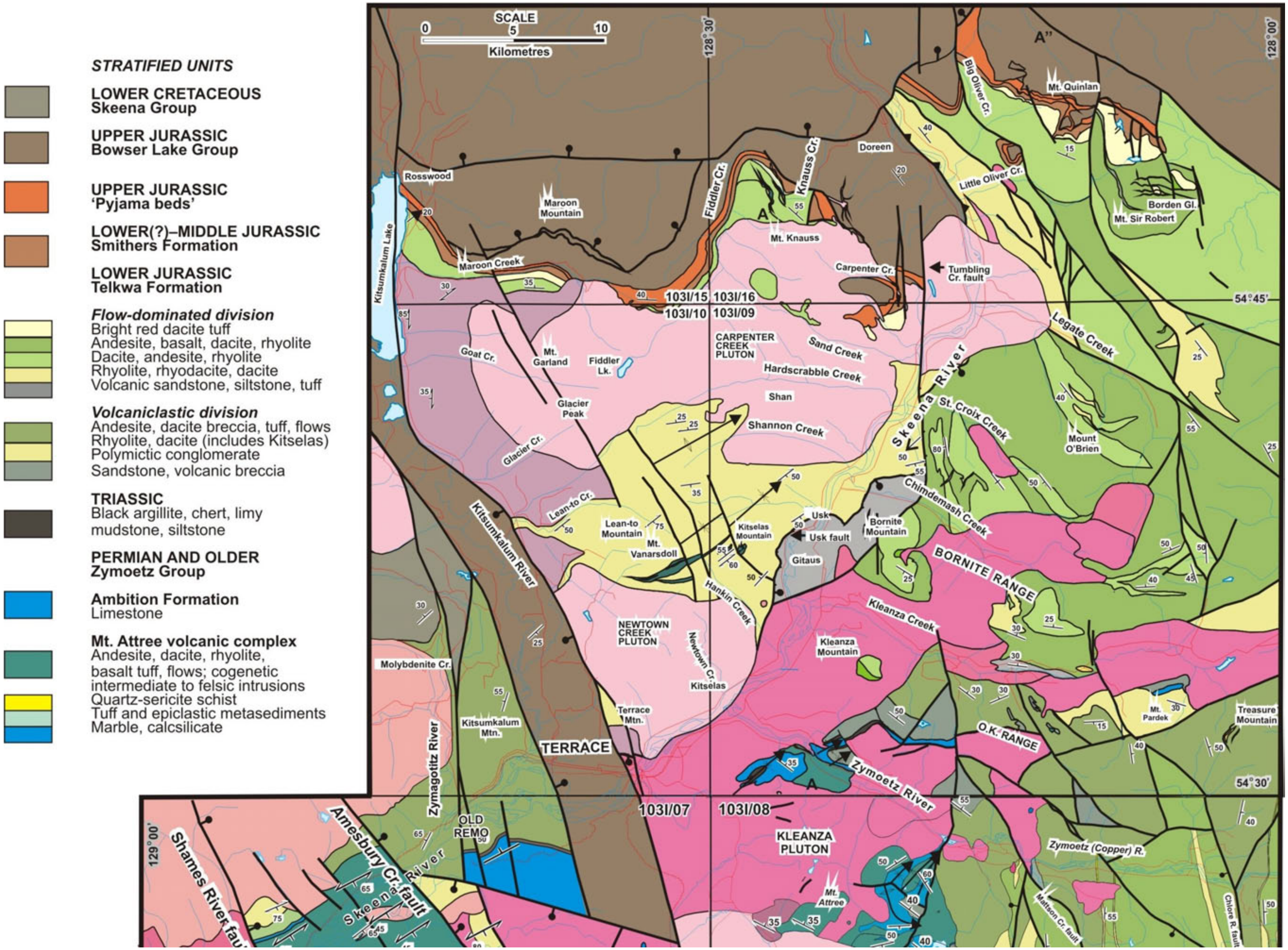
The westernmost outcrop along Highway 17 that is comparable to other Telkwa exposures lies east of the Amesbury Creek fault (Figure 3; 08JN27-03; UTM Zone 9, 514933E, 6036012N, NAD83). It consists of large-clast andesite breccia in which clasts contain millimetre-scale plagioclase phenocrysts, and augite-phyric basalt. Epidote patches and vein networks are prominent. Outcrops west of Amesbury Creek consist of greenstone and metadiorite of unknown age and possible subvolcanic origin, as well as abundant coarser plutonic rock types. No evidence was found to extend the Telkwa Formation west of the Amesbury Creek fault.

Intrusive Rocks

The region between Terrace and Kitimat is mainly underlain by plutonic bodies (Figure 3). They vary from gabbro and local ultramafite to true granite; their inferred ages range from possibly Paleozoic, through Early Jurassic, to Eocene. As there are few published U-Pb dates from the area, the very tentative age assignments that are offered here are based on lithological correlation and in some cases similarity of metamorphic grade and state of strain with dated bodies (including R. Friedman, pers comm, September 2008). There is clear opportunity in this area for a more detailed study of these intrusions than was possible within the scope of this project, which focused on stratified rocks and their enclosed deposits.

PALEOZOIC INTRUSIONS

Deformed plutonic rocks outcrop extensively on the north side of the Skeena River, east of the Shames River fault. They include tonalite, diorite and minor gabbro. At least some units are of Paleozoic age, as is shown by a Late Mississippian U-Pb zircon date of 331–317 Ma on a foliated metatonalite reported by Heah (1991). Foliated tonalite and granite on the north side of Williams Creek southeast of Terrace, described by Nelson et al. (2008a), are


STRATIFIED UNITS
LOWER CRETACEOUS
Skeena Group
UPPER JURASSIC
Bowser Lake Group
UPPER JURASSIC
'Pyjama beds'
LOWER(?)–MIDDLE JURASSIC
Smithers Formation
LOWER JURASSIC
Telkwa Formation
Flow-dominated division
Bright red dacite tuff
Andesite, basalt, dacite, rhyolite
Dacite, andesite, rhyolite
Rhyolite, rhyodacite, dacite
Volcanic sandstone, siltstone, tuff
Volcaniclastic division
Andesite, dacite breccia, tuff, flows
Rhyolite, dacite (includes Kitselas)
Polymictic conglomerate
Sandstone, volcanic breccia
TRIASSIC
Black argillite, chert, limy mudstone, siltstone
PERMIAN AND OLDER
Zymoetz Group
Ambition Formation
Limestone
Mt. Attree volcanic complex
Andesite, dacite, rhyolite, basalt tuff, flows; cogenetic intermediate to felsic intrusions
Quartz-sericite schist
Tuff and epiclastic metasediments
Marble, calcsilicate
SCALE
0 5 10
Kilometres
128°30'
128°00'
54°45'
54°30'
129°00'
A"
A
Mt. Quinlan
Big Oliver Cr.
Little Oliver Cr.
Borden Gl.
Mt. Sir Robert
Doreen
Knauss Cr.
Fiddler Cr.
Mt. Knauss
Carpenter Cr.
Tumbling Cr. fault
Rosswood
Maroon Mountain
Maroon Creek
Kitsumkalum Lake
103I/15
103I/16
103I/10
103I/09
CARPENTER CREEK PLUTON
Sand Creek
Hardscrabble Creek
Shan
Shannon Creek
Legate Creek
Skeena River
St. Croix Creek
Mount O'Brien
Goat Cr.
Mt. Garland
Fiddler Lk.
Glacier Peak
Glacier Cr.
Lean-to Cr.
Lean-to Mountain
Mt. Vanarsdoll
Kitselas Mountain
Usk
Usk fault
Gitaus
Bornite Mountain
Chimdemash Creek
BORNITE RANGE
Kleanza Creek
Kleanza Mountain
Hankin Creek
Kitsumkalum River
NEWTOWN CREEK PLUTON
Newtown Cr.
Kitselas
Molybdenite Cr.
Kitsumkalum Mtn.
Terrace Mtn.
TERRACE
Zymagotitz River
O.K. RANGE
Mt. Pardek
Treasure Mountain
Zymoetz River
103I/07
103I/08
OLD REMO
KLEANZA PLUTON
Mt. Attree
Zymoetz (Copper) R.
Mattson Cr. fault
Chlore R. fault
Amesbury Cr. fault
Skeena River
Shames River fault

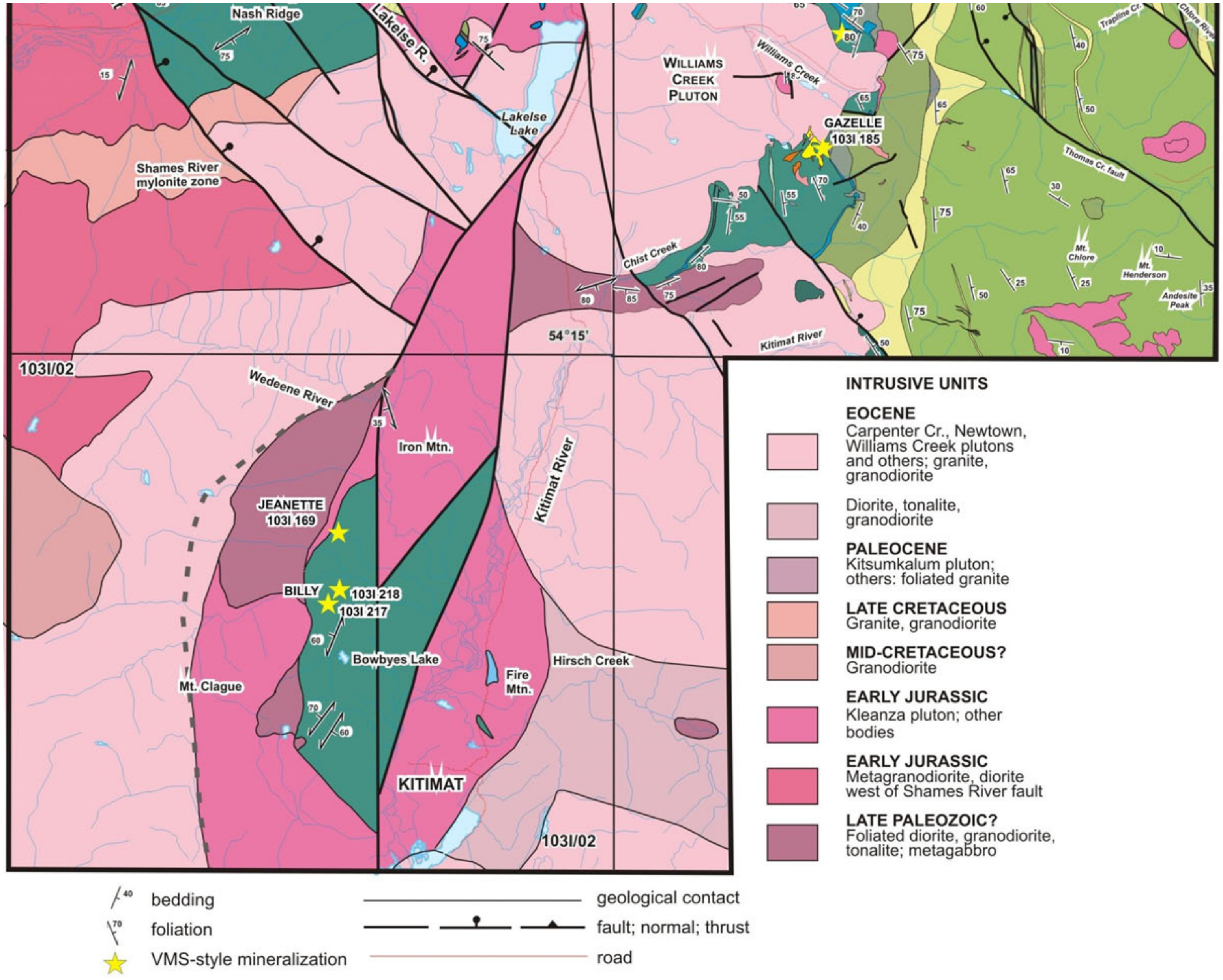


Figure 2. Geology of the Terrace area, compiled from field mapping at 1:20 000 scale in 2005–2008 (Nelson et al., 2006b, 2007, 2008b), with additional data from Woodsworth et al. (1985) and Heah (1991).

also Late Mississippian (R. Friedman, U-Pb zircon data, pers comm, September 2008), suggesting that they are part of the same suite. In contrast to younger plutonic bodies northeast of the Shames River fault, these Paleozoic intrusions are dynamically metamorphosed. Metamorphic grades are upper greenschist to lower amphibolite. Syn- and postkinematic hornblende, indicative of relatively higher-temperature, amphibolite-grade conditions, occurs in a few localities within their westernmost extent.

West of Kitimat, foliated quartz-eye dacite and greenstone of probable Paleozoic age (*see* description above) are interlayered with foliated quartz-eye tonalite and diorite. They probably represent a suite of cogenetic intrusions and extrusive rocks. Opaline quartz phenocrysts are identical in volcanic and plutonic rocks, and lithologic contacts are transposed into the foliation. A sample of metatonalite has been collected for U-Pb dating. As this volcanic-intrusive unit is traced west onto Mt. Clague, the extrusive component disappears and coarser metagabbro and metapyroxenite become prominent together with tonalite and diorite. Along strike to the north, between Raley and Dahl creeks, is a metamorphosed mafic complex of diorite, gabbro, plagioclase and augite porphyry, and plagiogranite. It is characterized by extreme compositional and textural variations on a small scale, but an overall large-scale homogeneity. Contacts between phases are highly irregular and nonplanar, suggesting coeval emplacement in a subvolcanic environment. A Paleozoic age is suggested based on its continuity with volcanic-intrusive rocks near Kitimat, and on the characteristic irregular shape of plagioclase phenocrysts in andesitic phases, which closely resemble those in porphyritic andesite of the Mt. Attree volcanic complex near Williams Creek (Figure 7).

Metamorphosed layered gabbro, peridotite and clinopyroxenite occur in a 500 m wide inlier surrounded by younger intrusive rocks on the north side of Hirsch Creek near the southeastern corner of the map area (Figure 3). Augite is pseudomorphed by coarse crystalline actinolite, and olivine has been converted to serpentine and talc. This body is tentatively assigned a Paleozoic age by correlation with the mafic complex described above, and from its pervasive greenschist metamorphism, which is not seen to affect the known Early Jurassic and younger intrusive bodies.

EARLY JURASSIC INTRUSIVE ROCKS

Unmetamorphosed diorite, microdiorite, granodiorite, gabbro and minor hornblendite underlie large parts of the valley between Terrace and Kitimat. They occur on the hill southeast of the confluence of the Kitimat and Skeena rivers, on Mt. Herman, along the Wedeene River, at the base of Iron Mountain, on Fire Mountain and in road outcrops within the town of Kitimat. Except for the microdiorite, this

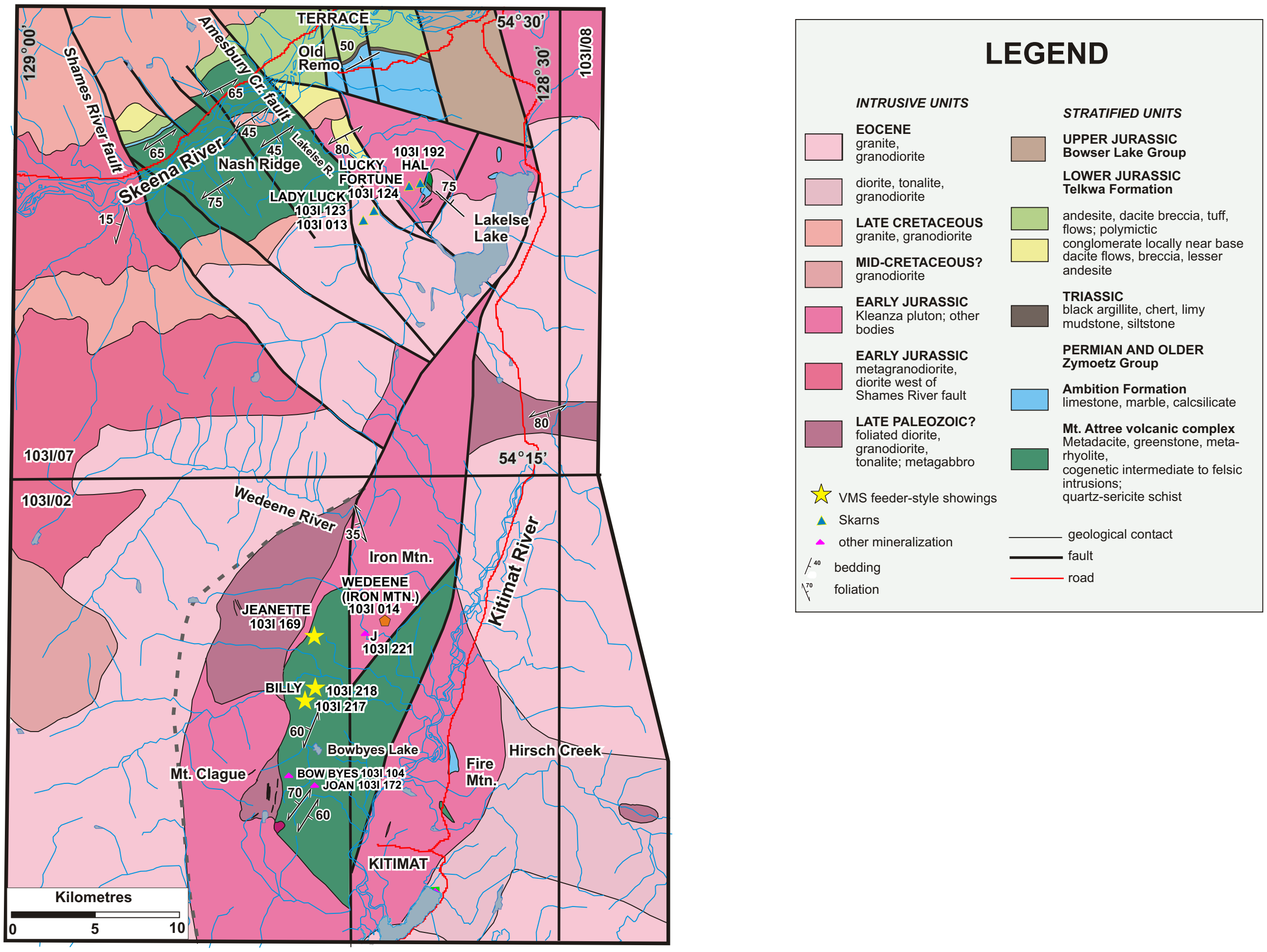


Figure 3. Geology of the Terrace-Kitimat valley and adjacent Coast Mountains, compiled from 1:20 000 field maps completed in 2008 and data from Woodsworth et al. (1985) and Heah (1991).

suite is coarse grained and equigranular to somewhat inequigranular. Transitional contacts between coarse-grained phases indicate that this suite probably forms a single large pluton that cooled at significant depth. In one instance of possible subvolcanic character, intrusive breccia textures are well developed along the logging road on the west side of the hill near the Kitimat-Skeena confluence, near an assumed intrusive contact with the Telkwa dacite. Hornblendes in all phases of the suite are fresh. Augite, where present, appears actinolized. For the most part, these rocks are undeformed, except for brittle shearing in outcrops in Kitimat, possibly due to local faulting. Textural and compositional variability characterize this suite, although not to the same degree as in the Raley-Dahl mafic complex (*see* above). Individual phases occur on hundred metre to kilometre scales. The compositional range from gabbro to granodiorite, as well as the overall textures and presence of characteristic phases like microdiorite and coarse hornblendite, all support correlation with the Early Jurassic Kleanza pluton, exposed north and east of the current area (Figure 2).

A body of fresh, coarse-grained, weakly foliated hornblende-biotite tonalite and diorite intrudes the Paleozoic (?) metaintrusive complex near the summit of Mt. Clague. It contains decimetre-scale rafts of strongly foliated greenstone. It was emplaced, therefore, after the development of the transposition foliation in older rocks, but was affected by regional northeasterly deformation. It may be Early Jurassic, or even Cretaceous in age. A sample has been collected for U-Pb dating.

Large areas west of the Shames River fault are underlain by gneissic granodiorite and diorite, dated at ca. 188 Ma by U-Pb in zircon (Heah, 1991). This is somewhat younger than dates obtained from the Telkwa Formation and Kleanza pluton, ca. 200–195 Ma (Gareau et al., 1997; Nelson et al., 2008a).

LATE CRETACEOUS INTRUSIONS

Late Cretaceous, ca. 70 Ma granodiorite underlies high ridges north of the Skeena River west of Terrace (Heah, 1991). A small body of quartz-rich granodiorite, tonalite and diorite, also assumed to be Late Cretaceous (Heah, 1991), outcrops along the road south of the Skeena River, west of the Lakelse River crossing (Figure 2). This body is weakly metamorphosed in the lower greenschist facies. It shows both local ductile and more prevalent brittle, northeasterly foliations that are congruent with the stronger fabrics in Paleozoic metadacite that it intrudes.

Slightly metamorphosed and foliated granodiorite outcrops on a hill located 2.5 km east of the Lakelse River outlet, opposite from the body described above. It is inferred to represent a fault offset in the down-faulted valley bottom (Figure 3). It intrudes weakly foliated Telkwa dacite, and diorite and intrusive breccia of probable Early Jurassic age.

A body of variably foliated quartz-rich granodiorite and granite occurs on Nash Ridge, where it intrudes Paleozoic metavolcanic rocks. Heah (1991) considered it to be Late Cretaceous, a correlation that is consistent with its compositional and textural resemblance to intrusions farther north.

EOCENE INTRUSIONS

White granite and granodiorite outcrop both east and west of Lakelse Lake and extend farther west into the Coast Mountains. Compared to the intrusions of inferred Jurassic age, these exhibit much more homogeneous, more felsic

Figure 4. Representative felsic textures, Mt. Attree volcanic complex: **a)** opaline quartz-eye porphyry dacite (metatuff), east slope of Mt. Clague, 08JN05-08, UTM Zone 9, 517824E, 5993220N, NAD83; hammer head for scale; **b)** ovoid quartz-eye porphyry from small, subvolcanic intrusion, Nash Ridge; 08JN21-04, UTM 514517E, 6026691N, pen for scale; **c)** dacite breccia with white rhyolite clast, near Bowbyes Lake, 08JN01-02, UTM 578403E, 5998115N, pencil for scale.

and more quartz-rich compositions. This broad area of felsic plutonic exposure is apparently continuous with the Eocene Williams Creek pluton to the east (Figure 2; R. Friedman, U-Pb date, pers comm, September 2008). Planar pink pegmatite and aplite dikes are present in places (Figure 9b). Biotite is more abundant than hornblende, and both are unaltered and fresh. A key identifying characteristic is the presence of millimetre-scale, clear, euhedral, amber-coloured titanite grains. The rocks are massive and are interpreted to postdate the penetrative deformation that affects Late Cretaceous and older units.

Massive, medium-grained equigranular diorite, tonalite and granodiorite occur together east of Fire Mountain in the lower Hirsch Creek drainage in the southeastern corner of the map area. Tonalite dike complexes in diorite and intrusive breccia of diorite in tonalite show curviplanar phase contacts suggestive of magma mixing. The age of this body is unknown; it is unlike the Early Jurassic suite, and may be a relatively mafic Eocene intrusion.

Structure and Metamorphism

NORTHEASTERLY FOLDING

Fieldwork in 2007 (Nelson et al., 2008a, b) identified a northeast-trending, regional anticline outlined by the curved outcrop pattern of the Permian limestone, which strikes north-northeast near Chist Creek, changing to north-northwest on the ridge south of Williams Creek, west-northwest on the ridge east of Mt. Attree and is deformed into a series of northeasterly folds in the hinge area in the Zymoetz River valley and on Copper Mountain (Figure 2). Rocks of the pre-Permian Mt. Attree volcanic complex occupy the anticlinal core. Mapping in 2008 extends the north limb of the regional culmination across the valley south of Terrace and into the Coast Mountains as far west as the Shames River fault. A band of east-striking, north-dipping Permian limestone extends across the valley near Old Remo; farther west, marble separates Paleozoic from Telkwa exposures in a northwesterly overturned section north of the Skeena River and east of the Shames River (Figures 2, 3). Structural continuity is indicated across the normal faults that bound the valley. South and downsection from the westernmost limestone, metavolcanic and metaintrusive rocks correlated with the Mt. Attree volcanic complex outcrop in the eastern Coast Mountains as far south as Kitimat, on trend with the anticlinal core, as defined farther northeast (Figure 2). Texturally identical, opaline quartz-phyric volcanic units occur on Nash Ridge in the north and on Mt. Clague to the south, on opposite sides of the projection of the Shames River fault. A possible explanation for the implied structural anomaly is outlined below.

Northeasterly foliations are only locally developed in the Telkwa Formation in the valley south of Terrace. In contrast, northeasterly foliations are strongly developed in Paleozoic greenschist-facies dacite and tonalite west of the Amesbury Creek fault. The schistosity and transposition in these rocks are similar to those in metavolcanic schist at lower topographic elevations near the mouth of Chist Creek (*see* Nelson et al., 2008a). Intrusive rocks as young as Late Cretaceous show development of northeasterly fabrics, which are axial planar to the anticline. Fabrics in Late Cretaceous granitoid rocks are not as penetrative as in the host metavolcanic and metaplutonic rocks, suggesting that the plutons were emplaced during deformation and metamor-

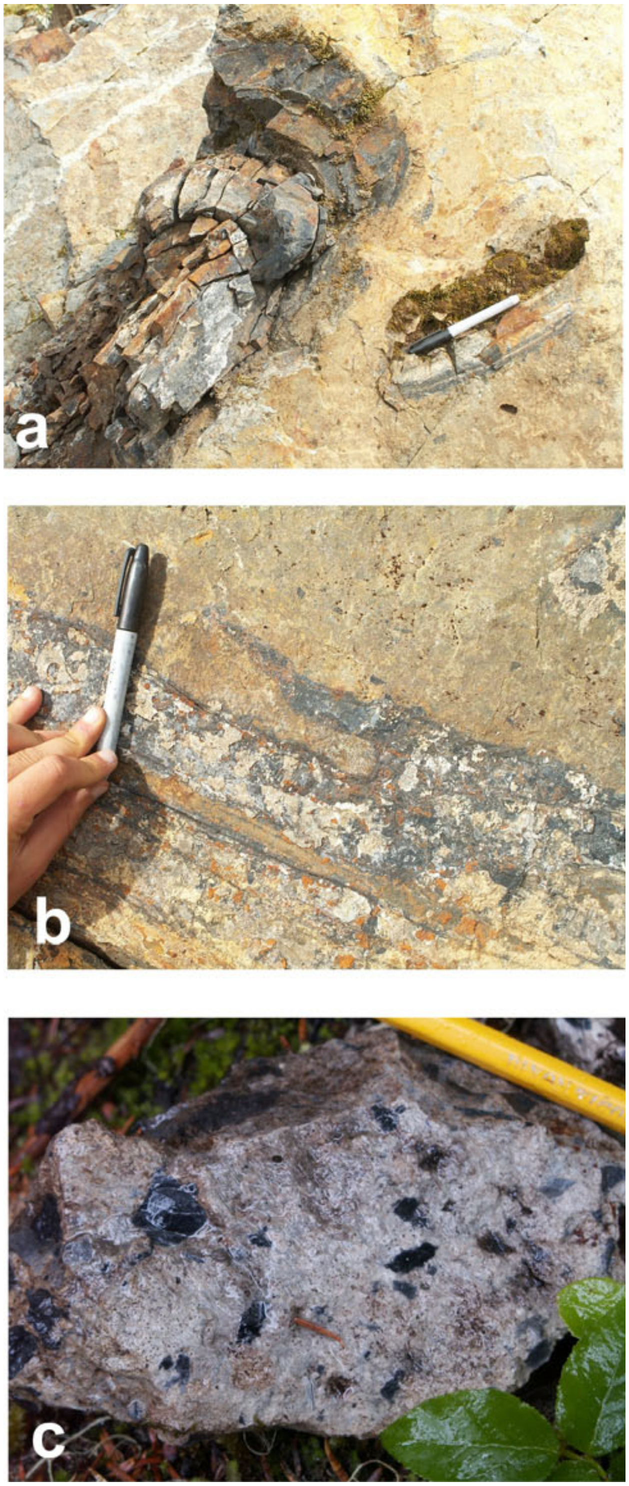


Figure 5. Contrasting relationships between the Triassic sedimentary unit and volcaniclastic units: **a)** folded Triassic sedimentary inclusion in basalt breccia quarry east of Old Remo, 07JA11-3, UTM Zone 9, 520025E, 6036282N, NAD83; fold development appears to have been penecontemporaneous, probably related to inclusion within pyroclastic flow, pen for scale; **b)** contact between basalt breccia and inclusion of Triassic sedimentary strata, quarry east of Old Remo, 07JA11-3, pen for scale; note wispy, soft-sediment contact; **c)** highly angular, lithified Triassic chert clasts in basal Telkwa conglomerate from Kleanza Mountain north of Zymoetz River, 05NB13-01, UTM 542849E, 6043341N, pencil for scale.

phic cooling. Strongly foliated, garnet-bearing granitoid rocks in Williams Creek are not Paleocene, as suggested by Nelson et al. (2008a, b), but likely Mississippian (R. Friedman, pers comm, September 2008); their age does not date the deformation as Paleogene. An upper limit on deformation is established by Eocene bodies, including the dated Williams Creek pluton as well as its inferred correlatives farther west, which cut these fabrics. This constrains the folding event to Late Cretaceous age.

Besides age, three factors influence the degree of northeasterly fabric development associated with the regional folding event: stratigraphic level, location and rock composition. First, stratigraphic level is considered the most important. Foliation in Telkwa volcanic units is weak, sporadic and widely spaced. The same is generally true of the Permian limestone and Triassic sedimentary unit. In continuous exposures, for instance near Chist Creek, foliation becomes increasingly penetrative, and metamorphic grade increases downsection in the Mt. Attree volcanic complex. The highest metamorphic grades occur at the lowest exposed stratigraphic levels: east of the Kitsumkalum-Kitimat valley near the mouth of Chist Creek and along the Kitimat River, where knotted green biotite schist contains cordierite with relict garnet cores, and west of the valley in the eastern Coast Mountains, where schist is common.

Second, in any given unit, intensity of foliation development increases along with metamorphic grade in a northeast direction. East of and within the valley near Terrace, Telkwa volcanic rocks are at incipient greenschist grade (first growth of actinolite) or lower; only in the far west do greenschist minerals, actinolite and chlorite, define a foliation. Permian fossiliferous limestone near Old Remo is equivalent to highly foliated marble near the Shames River.

Last, rock type exerts an influence: Early Jurassic gabbro and diorite show only rare weak foliation, as do mafic complexes of inferred Paleozoic age, for instance, the one between Raley and Dahl creeks. Even within the Paleozoic volcanic-intrusive unit, highly foliated metadacite and tonalite is interlayered with apparently unfoliated greenstone and diorite. All of these features are characteristic of a folding event that affected upper crustal rocks in greenschist conditions, in which temperature increased with depth and towards the west.

NORMAL FAULTS

The northwest-striking Shames River fault (Figures 2, 3) is a listric, down-to-the-northeast normal fault. This fault has accommodated an estimated total of 6–9 km, based on contrasting pressure-temperature conditions across it (Heah, 1991; Andronicos et al., 2003). All of the stratified rocks and the regional northeasterly fold, described above, with the exception of those near Kitimat, lie in its hangingwall. Its footwall to the west near the Skeena River is occupied by the low-angle Shames River mylonite zone (SRMZ), which also shows a top-to-the-northeast, normal sense of displacement involving Early Jurassic orthogneiss, Late Cretaceous and Eocene granite, and older gneiss (Figure 8a). Both mylonitic deformation in the SRMZ and normal faulting are constrained as Eocene, ca. 54 to ca. 47 Ma (Andronicos et al., 2003; Heah, 1991). They have been interpreted to record progressive tectonic denudation of the core of the Coast Mountains during regional transtension.

Figure 6. Small plagioclase-phyric dacite from Telkwa Formation, 08JN15-03, UTM Zone 9, 520701E, 6032249N, NAD83, quarry on Thunderbird Main logging road, rock hammer for scale.

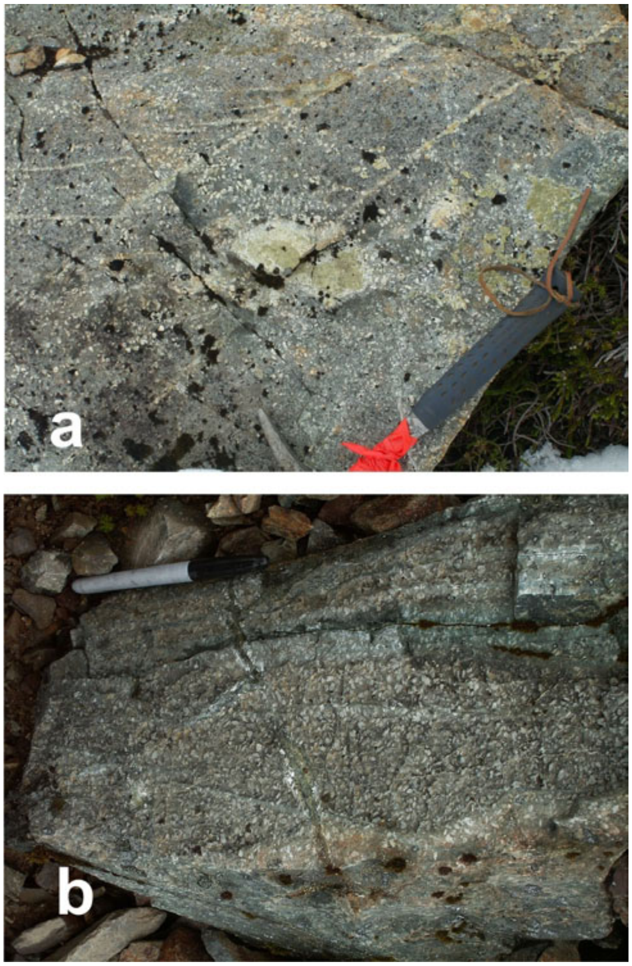


Figure 7. a) Raggedly terminated plagioclase phenocrysts in andesite, mafic intrusive complex on ridge between Raley and Dahl creeks, 08JN13-04; UTM Zone 9, 512470E, 6003608N, NAD83, rock hammer for scale. **b)** Typical Mt. Attree andesite, north of Williams Creek, pen for scale. Note identical plagioclase morphologies in a) and b).

The Amesbury Creek fault is a northeasterly analogue of the Shames River fault, similarly northwest striking, with the northeast block down. The displacement on it is perhaps 600–800 m of vertical offset, based on the outcrop elevations of the Permian limestone to the east and west (Figures 3, 8b). It separates mainly Paleozoic volcanic and intrusive rocks to the west from Permian limestone, Triassic sedimentary beds and Telkwa Formation within the valley south of Terrace.

The Kitsumkalum-Kitimat graben coincides with the deep intermontane valley that extends from New Aiyansh along the Nass River to Kitimat. Stratigraphic throw on its bounding faults can be estimated from offset of the Permian limestone, which lies at elevations of 1 000 m east of the valley and 100–200 m within the valley, and would crop out above present erosion levels to the west where underlying volcanic units are exposed. No Paleozoic volcanic units are found within the graben; they are presumed to underlie the younger rocks.

The sense of motion on its eastern bounding fault is indicated in outcrops east of Kitsumkalum Lake, where minor synthetic structures show ductile and brittle down-to-the-west and dextral sense of motion (Nelson and Kennedy, 2007). It juxtaposes greenschist-facies Kitselas metavolcanic rocks to the east with unmetamorphosed Bowser Lake Group (shale or siltstone?) along the Kitsumkalum River. Between Terrace and Lakelse Lake, the southern extension of this fault is not exposed. Geological interpretations favour an anastomosing fault system between Lakelse Lake and Kitimat, but there are no exposures of high stratigraphic levels in that part of the valley, suggesting that it is not floored by a graben there. South of the Wedeene River, a quarry in mylonitized granodiorite (Figure 8c) shows thrust-sense, top-to-the-northeast motion on north-northwest striking, west-dipping surfaces and low-plunge (173°/05°N) slickensides indicative of transcurrent motion. The outcrop is near the projected location of one of the important fault strands.

Inferences from geological mapping in 2008, along with compilation from mapping by Woodsworth et al. (1985) and Heah (1991), show that the main Kitsumkalum fault is deflected into a gentle eastward arc near Lakelse Lake (Figure 2). The Shames River and Amesbury Creek faults can be projected eastward as far as this fault; however, further extensions are incompatible with mapped geological relationships farther east, and for this reason they are interpreted to terminate against the main fault near Lakelse Lake. The fault geometry would form a complex flower structure within a releasing bend in a dextral fault system. It explains the prevalence of tilted fault blocks south of Terrace and the graben-within-graben, downdropped panel of Bowser Lake Group farther north.

In this view, the normal-dextral fault east of Kitsukalum Lake and in fact the entire Kitsumkalum-Kitimat graben were coupled to Eocene normal motion on the Shames River and Amesbury Creek faults, as parts of a transtensional, partitioned system. Dating of fabrics in the Kitsumkalum pluton would provide a test of the suggested geometry.

A major unsolved structural problem associated with the map compilation of Figure 2 concerns the distribution of Paleozoic metavolcanic rocks west of the valley. Opaline quartz-phyric dacite on the south side of the Skeena River and on Nash Ridge is identical to that near Kitimat. Not only are these outcrops located across nearly 30 km of

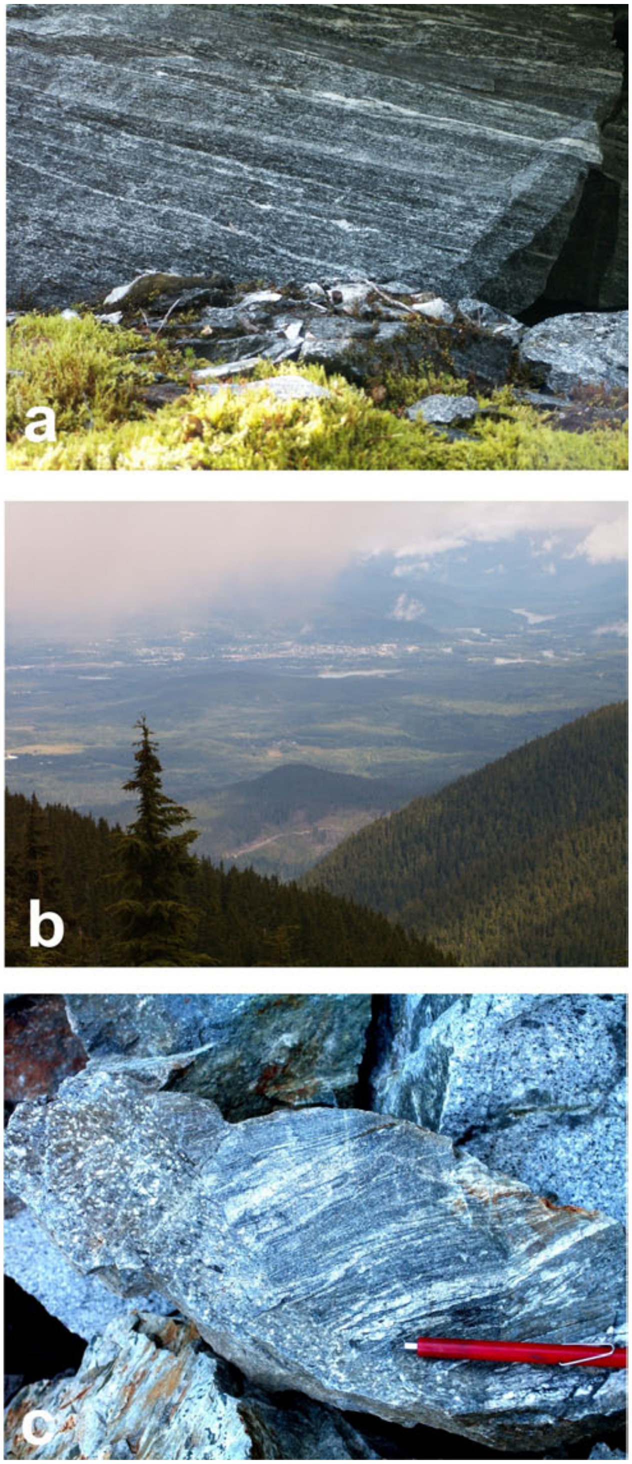


Figure 8. a) Top-to-the-east (left in photograph) mylonitic fabric developed in Early Jurassic orthogneiss, Shames River mylonite zone south of the Skeena River; 08JN25-01, UTM Zone 9, 506916E, 6026292N, NAD83. **b)** Looking from Paleozoic volcanic exposures on Nash Ridge, northeast across the concealed Amesbury Creek fault into the Kitsumkalum-Kitimat graben. The low hill in the middle distance is underlain by Late Cretaceous granite, Early Jurassic diorite and dacite of the Telkwa Formation. **c)** Less-deformed plagioclase porphyry intruding mylonitized granodiorite south of Wedeene River, 08JN26-03; UTM 520590E, 6009325N, pen magnet for scale.

Table 1. Geochemical and assay results from 2008 for the NTS 103I/02 and 07 map areas. Elevated values indicating higher mineral potential are highlighted in yellow.

			Element	**Cu**	**Pb**	**Zn**	**Ag**	**Au**	**Mo**	**Cd**	**As**	**Sb**	**W**	**Hg**	**Ba**
			Unit	***ppm***	***ppm***	***ppm***	***ppb***	***ppb***	***ppm***	***ppm***	***ppm***	***ppm***	***ppm***	***ppb***	***PPM***
			Method	***ARMS***	***ARMS***	***ARMS***	***ARMS***	***ARMS***	***ARMS***	***ARMS***	***ARMS***	***ARMS***	***ARMS***	***ARMS***	***ARES***
			Lab	***ACM***	***ACM***	***ACM***	***ACM***	***ACM***	***ACM***	***ACM***	***ACM***	***ACM***	***ACM***	***ACM***	***acm***
			Detection Limit	0.01	0.01	0.1	2	0.2	0.01	0.01	0.1	0.02	0.1	5	1
Field No.	**UTM E**	**UTM N**	**Description**												
08JN01-04	517335	5996907	Billy; srongly silicified zone with wispy pyrite, possible barite	12.93	1.26	36.4	59	8.4	1.69	0.02	2.2	-0.02	-0.1	14	
08JN02-01	518036	5997674	Billy (Gold zone?): representative grab, 5% pyrite in silicified dacite	79.13	11.5	23.9	1727	22.7	2.08	0.04	112	1.61	0.7	50	
08JN02-04	518140	5998299	Billy Barite showing; barite, silcification; pyrite, trace galena, mt, cpy	108.45	42.58	28.9	2178	92.1	75.66	0.07	12.3	0.34	1	15	>50000
08JN04-01	517659	6001837	Jeannette showing, high grade chalcopyrite-rich grab from 25 cm thick zone	**4.75%**	2.87	165.5	15403	4710.1	25.75	1.14	4.6	0.02	-0.1	20	
08JN07-02	516392	6030797	silicified, pyritic quartz-eye phyric metadacite	49.79	0.51	16.1	41	3.3	0.85	0.01	0.8	0.04	-0.1	-5	
08JN07-05	512928	6031122	zone of rich pyrite, magnetite in quartz-phyric metadacite, south Skeena	64.49	0.37	66.2	162	7.7	0.27	0.02	0.4	0.02	-0.1	-5	
08JN11-05	537933	6014644	silicified, pyritic zone in ductile shear cutting fine grained greenstone	961.5	2.12	8.2	1613	46.5	22.47	0.11	3.9	0.03	0.4	-5	
08JN13-03	512419	6003594	1 m thick greisen near edge of Eocene pluton; contains pyrite, maybe trace chalcopyrite	69.35	0.83	29.3	58	3.1	1.22	-0.01	1.9	0.06	-0.1	-5	
08JN14-01	528972	6031008	pods of pyrite, pyrrhotite skarn in metamorphosed Permian limestone	24.44	10.56	49.5	79	0.9	0.69	0.45	3.3	0.22	0.1	-5	
08JN14-05-1	528582	6029456	skarn pod in Permian marble northwest end Lakelse Lake - sphalerite - rich high-grade grab sample	268.94	21.02	**12.44%**	2284	42	1.49	859.13	11.4	0.06	7.8	517	
08JN14-05-2	528582	6029456	skarn pod in Permian marble northwest end Lakelse Lake - contains sphalerite, stibnite, chalcopyrite	414.89	7.78	94.7	1106	7.6	10.62	0.5	36.5	0.44	0.1	-5	
08JN14-06	528460	6029329	skarn in limestone, minor sphalerite	7.84	1.11	148.6	66	0.6	1.69	0.63	17.9	0.23	0.8	-5	
08JN14-13	524718	6028703	pyrrhotite-rich skarn in Permian limestone	148.94	2.69	54.2	352	3.1	28.12	0.27	2.1	0.14	0.3	-5	
08JN21-04	514517	6026691	quartz-sericite schist with pyrite, Nash Ridge	20.43	2.05	55.3	299	26.9	4.24	0.08	1	0.03	-0.1	-5	
08JN22-06	515710	6027083	quartz-sericite schist with pyrite, Nash Ridge	9.18	1.14	39.7	86	16.1	3.31	0.01	0.5	0.02	-0.1	70	
08JN24-03	514853	6026880	quartz-sericite schist with pyrite, Nash Ridge	362.06	1.54	64.5	216	6.8	2.2	0.11	1.5	-0.02	-0.1	-5	
08JN26-01	522440	6001971	J showing - pyritic shear in greenstone	77.01	0.57	302.7	86	23.5	8.68	0.06	0.4	-0.02	-0.1	-5	

Analysis of steel milled crushed rock prepared by ACME Analytical. Duplicate on crushed rock
ARMS = Aqua regia digestion - ICPMS. 15 g sample
ARES = Aqua regia digestion - ICPES
ACM = ACME Analytical, Vancouver
% Difference = ABS ((x1-x2)/(x1+x2)/2)x100
Acme report VAN08009445

structural (and assumed stratigraphic) strike, they are on opposite sides of the Shames River fault, interpreted to have a vertical offset of 6–9 km where it crosses the Skeena River (Heah, 1991; Andronicos et al., 2003). This geometry could be accommodated by a western splay of the main valley fault, shown as the dashed grey line on Figure 3. Restoration of >20 km of dextral motion across such a fault could restore the Nash Ridge Paleozoic sequence close to the Mt. Clague rocks. This fault, part of the Shames River–Kitsumkalum–Kitimat system, would have to offset rock bodies as young as 52–47 Ma. A traverse in 2008 across the eastern edge of the Eocene (?) granite on the ridge between Raley and Dahl creeks discovered a clearly intrusive contact, with extensive local pegmatite development, greisen and hornfelsing. On the other hand, the pluton has not been precisely dated and may be composite, and shear zones may lie farther west within it.

MINERAL OCCURRENCES AND MINERAL POTENTIAL

Southwestern Extension of Paleozoic VMS Belt

In 2007, the recognition of indicators of significant volcanogenic massive sulphide potential within the Paleozoic Mt. Attree volcanic complex added new mineral potential to the Terrace area (McKeown et al*.*, 2008). The most significant zones of quartz-sericite-pyrite schist with associated small base-metal showings were on and near the Gazelle property at the height of land between Chist Creek and Williams Creek. Projection of the mainly northeasterly trending zones and their hostrocks to the southwest led to the hypothesis that the belt could be exposed in the eastern Coast Mountains northwest of Kitimat. Review of geological data in an assessment report support this, as showings of inferred VMS style had previously been documented in the Wedeene River area (Belik, 1987). The report was accompanied by a 1:20 000 scale outcrop-based geological map of high quality that became of great value in guiding our work in the area, through dense bush and overgrown logging roads.

Belik (1987) reported three main showings of possible volcanogenic character in metavolcanic hostrocks: Billy (MINFILE 103I 218), Billy Barite (MINFILE 103I 217) and Jeannette (MINFILE 103I 169; Figures 2, 3). We confirmed these locations and evaluated and sampled the showings. All are of feeder style, alteration and vein systems transposed into the dominant northeasterly foliation. They are associated with quartz-rich dacite, rhyolite and minor rhyolite-clast breccia. Quartz-sericite-pyrite schist occurs at the Billy showings, in foliation-parallel pods distributed along 2 km of strike length. Belik (1987) reported assay results from a chip sample of the Billy ‘gold’ showing to be 2.4 g/t Au over 5 m, and a grab sample near the base of the zone that assayed 5.18 g/t Au, 32.9 g/t Ag, 0.7% Pb and 0.2% Zn. Our geochemical analysis of altered dacite at the Billy showing yielded unremarkable levels of base and precious metals (Table 1). The Billy barite showing (Figure 9a) is located on a logging landing north of the other showings. It is dominated by highly deformed, massive, coarse-grained barite, similar to the barite at the Sub showing, described by McKeown et al. (2008). High contents of barium in the assay analysis confirmed handsample mineral identification (Table 1). The barite is coarse grained and strongly deformed. It was emplaced as a vein or veins within the volcanic pile prior to folding and probably in a penecontemporaneous seafloor structure. Traces of visible sulphides—chalcopyrite, galena and sphalerite—are confirmed by slightly elevated values of Cu, Pb, Zn and Ag.

The Jeanette showing (MINFILE 103I 169) is in an overgrown trench next to a logging cut north of the Wedeene River (Figure 3). It is a silicified, northeast-striking shear zone that contains a zone 20–30 cm wide of semimassive pyrite and chalcopyrite. Assay results confirm the tenor of the mineralization: 4.75% Cu and 15.4 g/t Ag. Both the Jeannette and Billy showings are of epigenetic character. Their host metadacite and metarhyolite, however, match the typical hosts of volcanogenic deposits. Moreover, associated quartz-sericite-pyrite schist indicates that alteration occurred relatively early in the history, possibly near the time of their eruption on the seafloor. These showings are roughly on strike with the volcanogenic belt defined at the head of Chist Creek, and are considered to represent an extension. In 2007 and 2008, we identified a 30 km long belt of Paleozoic feeder-zone style, volcanogenic-associated mineralization. Preliminary geochronological results from Paleozoic rocks in the Terrace area are

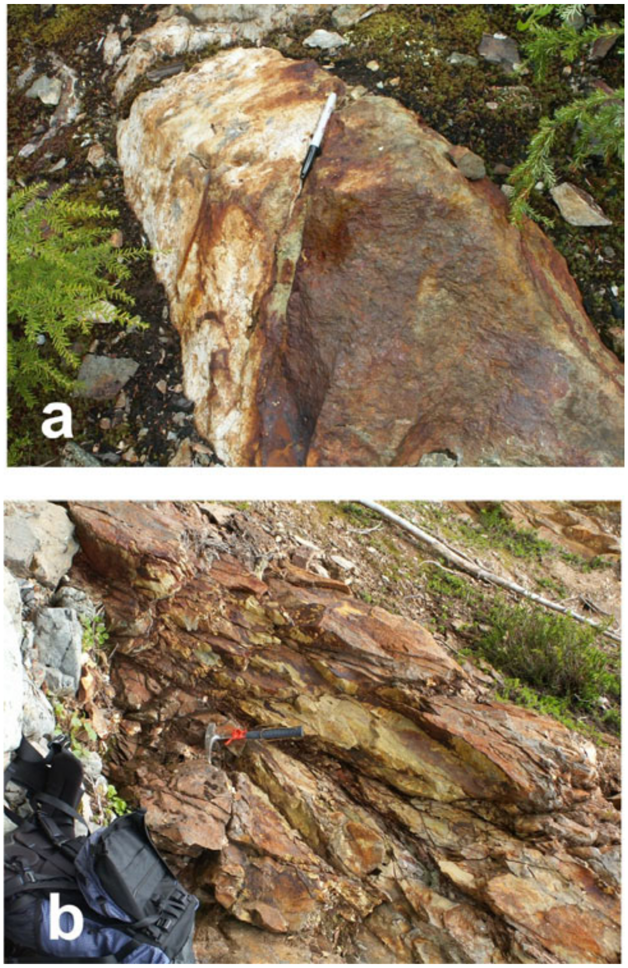


Figure 9. a) Billy barite showing; rusty massive barite with pyrite and traces of base-metal sulphides; 08JN02-04; UTM Zone 9, 518140E, 5998299N, NAD83, pen for scale; **b)** rusty quartz-sericite schist, Nash Ridge; 08JN 22-06; UTM 515710E, 6027083N, rock hammer for scale.

ca. 330–320 Ma (Heah, 1991; R. Friedman, pers comm, September 2008). These are compatible with a Late Mississippian age for the Chist Creek–Wedeene River volcanogenic belt, contemporaneous with the orebody at the Tulsequah Chief mine of far northwestern British Columbia, similarly hosted by Paleozoic volcanic strata of the Stikine terrane.

Quartz-sericite schist occurs regionally within the Mt. Attree volcanic complex west of the Terrace-Kitimat valley, for instance, on Nash Ridge (Figure 9b), and on the logging road south of the Skeena River, where very rusty quartz-sericite-chlorite schist hosts abundant pyrite and up to 10% magnetite (08JN07-05, Table 1).

Other showings on Mt. Clague and near the Wedeene River are minor shear-zone hosted or intrusion-related in character, and are of limited extent. This includes the 'J' showing (MINFILE 103I 221), a rusty shear zone on the bank of the Wedeene River opposite Iron Mountain (08JN26-01, Table 1), the Joan (MINFILE 103I 172), a zone of scheelite, magnetite and chalcopyrite and the Bowbyes (MINFILE 103I 114), a small zone of shear-hosted copper mineralization on the eastern slope of Mt. Clague.

West of Lakelse Lake, a number of contact skarn deposits are developed involving marbles of the Permian Ambition Formation, and Early Jurassic and Eocene intrusive bodies. Known showings of this type include the Lady Luck (MINFILE 103I 013, 103I 123), Lucky Fortune (MINFILE 103I 124) and Hal (MINFILE 103I 192). Mineralization comprises sphalerite, magnetite, molybdenite and chalcopyrite associated with epidote and garnet. In 2008, a previously undocumented skarn occurrence was discovered in a burrow pit near the northwestern shore of Lakelse Lake (08JN14-05-1, -2; Table 1). It contains at least one 30 cm wide zone of sphalerite-rich material, from which a sample returned over 12% Zn.

SUMMARY AND CONCLUSIONS

Field mapping in 2008 documented the continuation of a belt of Paleozoic volcanic rocks and enclosed VMS feeder-style mineralization from the Zymoetz River to the eastern Coast Mountains between Terrace and Kitimat. The Paleozoic volcanic unit, the Mt. Attree volcanic complex, forms the core of an unusually oriented, northeast-trending anticline that formed in latest Cretaceous to earliest Paleogene time. Its enclosed belt of VMS-related mineralization comprises zones of quartz-sericite-pyrite schist and local occurrences of deformed early epigenetic barite and rare base-metal sulphides. All of these are characteristic of feeder zones rather than seafloor exhalative deposits. The trend of the mineralized belt parallel to the regional northeasterly foliation and anticlinal hinge zone suggest that early northeasterly structures may have played a role in later crustal deformation.

The regional northeasterly folding event that controls distribution of the Mt. Attree volcanic complex is probably Late Cretaceous in age, as it affects ca. 69 Ma intrusive bodies near the Skeena River but not Eocene plutons. Northeasterly folding affected Paleozoic and younger strata both in the hangingwall of the Skeena River fault zone northeast of Terrace, and the Kitselas facies in its footwall (Nelson et al., 2008a; Angen, 2009). The deflection of the fault zone from north-northeast-striking to west-northwest-striking north of Legate Creek (Figure 2) may also result from northeasterly folding, a further indication that the folding event postdates the fault. The Skeena River fault zone has been interpreted as a mid-Cretaceous top-to-the-east thrust fault (Nelson et al., 2008a), that developed as part of the Skeena fold-and-thrust belt (Evenchick, 2001). Although northeast-trending folds are prominent in the Skeena fold-and-thrust belt, the folds near Terrace formed later, after the Skeena River fault zone, and cannot be ascribed to a mid-Cretaceous sinistral-transpressive event. They arose during an episode of orogen-parallel compression, possibly localized by a crustal-scale discontinuity that had earlier found surface expression in the Skeena arch.

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