New Geological Mapping and Implications for Mineralization Potential in the Southern and Western Whitesail Lake Map Area (NTS 093E), Southwestern British Columbia[1]

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KEYWORDS: Hazelton Group, Whitesail Lake, layered mafic intrusion, Central Gneiss Complex, Gamsby complex

INTRODUCTION

This investigation focuses on detailed bedrock mapping and economic mineralization potential in the southern and western Whitesail Lake map area (NTS 093E; Fig 1). Fieldwork in 2006 targeted the western and southwestern portions of the map area, specifically NTS 093E/04, 05, 06, 11 and 12. Mapping in these areas provides linkage to work completed in the southern portion of the Whitesail Lake map area under the Rocks to Riches Program (Mahoney *et al.*, 2005; Gordee *et al.*, 2005), and attempts to tie in with pre-existing mapping in the central portion of the map area (Fig 2). The primary objective of this investigation is to provide a comprehensive evaluation of potential for economic mineralization in the southern and western Whitesail Lake map area.

Objectives and Scope

The western and southwestern Whitesail Lake (NTS 093E) 1:250 000 map area straddles the transition zone between the Coast and Intermontane morphogeological belts, and is underlain by igneous and metamorphic rocks of the Coast Plutonic Complex on the west and Jurassic and Cretaceous volcanosedimentary successions of southwestern Stikinia on the east (Fig 1, 2). This boundary was examined to the south under the Bella Coola Targeted Geoscience Initiative (TGI; 2000–2004), which focused on constraining the geological evolution of the region and assessing the economic potential of Mesozoic volcanic assemblages and plutonic belts in the area (Haggart *et al.*, 2006). The geological framework established by the Bella Coola TGI was extended to the north, into the southern Whitesail Lake map area (NTS 093E/02, 03), under the Rocks To Riches Program in 2004. The geological setting and economic mineralization potential of Jurassic and Cretaceous stratified volcanosedimentary successions in the central portion of the Whitesail Lake map area have been documented previously by the British Columbia Geological Survey (1987–1990), and mapping conducted under the present project has been designed to link into this existing geological framework (Diakow and Mihalynuk, 1987; Diakow and Koyanagi, 1988; Diakow and Drobe, 1989; Diakow, 1990).

The current investigation focuses on 1:50 000 scale mapping and economic mineral assessment in the western and southwestern portions of the Whitesail Lake map area (093E/04, 05, 12 and parts of 093E/06 and 11). This project, sponsored by Geoscience BC, involves a combined research team from the University of Wisconsin – Eau Claire, the Geological Survey of Canada and the University of British Columbia. It seeks to improve our understanding of the geological evolution and economic mineral potential of the west-central portion of the Coast Mountains of British Columbia (53–54°N).

The primary focus of mapping during the 2006 field season was the western and southwestern portions of the Whitesail Lake map area, including portions of the Kitlope Lake (093E/04), Tsaytis River (093E/05), Chikamin Mountain (093E/06), Troitsa Peak (093E/11) and Tahtsa Peak (093E/12) 1:50 000 map areas (Fig 1–3). This region is underlain by Triassic, Jurassic and Cretaceous volcanic and sedimentary successions on the western edge of Stikinia, which have volcanogenic massive sulphide potential, and by Jurassic to Eocene plutonic bodies along the eastern margin of the Coast Plutonic Complex, which are known hosts for a variety of porphyry deposits (Woodsworth, 1980; Dawson *et al.*, 1991; Diakow *et al.*, 2002). This report briefly describes the geology of this region, based on detailed bedrock mapping during the 2006 field season (Fig 3). This investigation will integrate regional bedrock mapping, stratigraphic and structural analyses, geochronology, plutonic and volcanic geochemistry, isotopic analyses and mineral assays into a comprehensive assessment of the geological framework and economic mineral potential of the region.

Geological Setting

The geology of the western and southwestern Whitesail Lake map area can be described in terms of three northwest-trending lithological belts of sedimentary and metamorphic rocks that are intruded by plutons of primarily Jurassic, Cretaceous and Cenozoic ages. These lithological belts include, from east to west 1) unmetamor-

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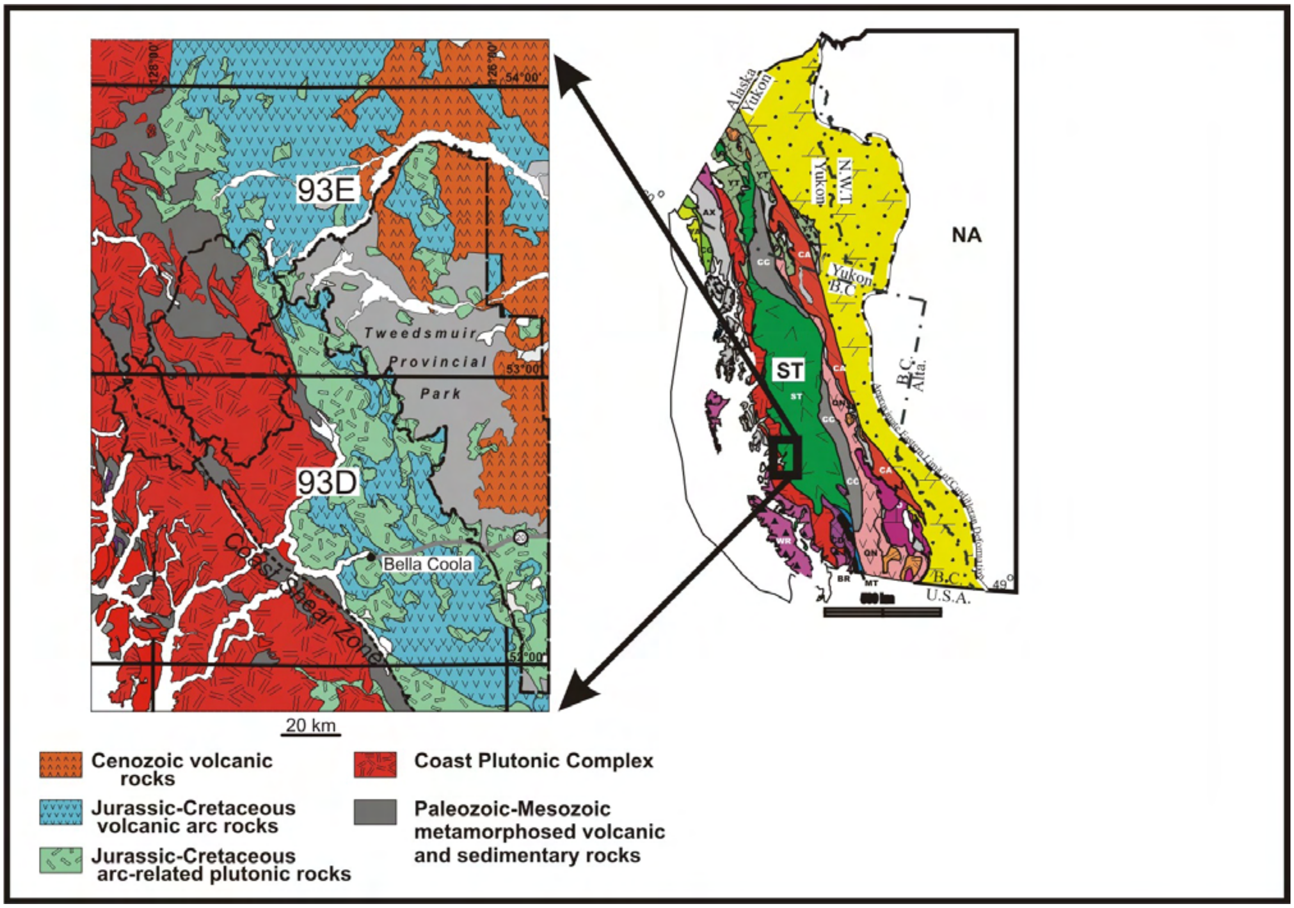

Figure 1. General geological setting of NTS 093D (Bella Coola) and 093E (Whitesail Lake) 1:250 000 map areas; inset is a schematic terrane map of the Canadian Cordillera, modified from Wheeler and McFeely (1991).

phosed to weakly metamorphosed supracrustal stratigraphic successions, including the Lower to Middle Jurassic Hazelton Group (and its weakly metamorphosed equivalents), Upper Jurassic sedimentary rocks, Lower Cretaceous Skeena Group, and Upper Cretaceous Kasalka volcanic rocks; 2) upper greenschist to upper amphibolite facies volcanic, sedimentary and plutonic rocks of the Triassic to Lower Jurassic (?) Gamsby complex; and, 3) high-grade metamorphic rocks of the Central Gneiss Complex. These lithological packages are described sequentially below, from east to west.

EASTERN LITHOLOGICAL BELT

HAZELTON GROUP (UNIT Jh)

The western and southern Whitesail Lake map area contains some of the southernmost exposures of the Lower to Middle Jurassic Hazelton Group (Woodsworth, 1980; Gordee *et al.*, 2005). The stratigraphy, geochronology and geochemistry of the Hazelton Group in the southern Whitesail Lake map area (NTS 093E/02, 03) were documented during a regional assessment of potential Eskay

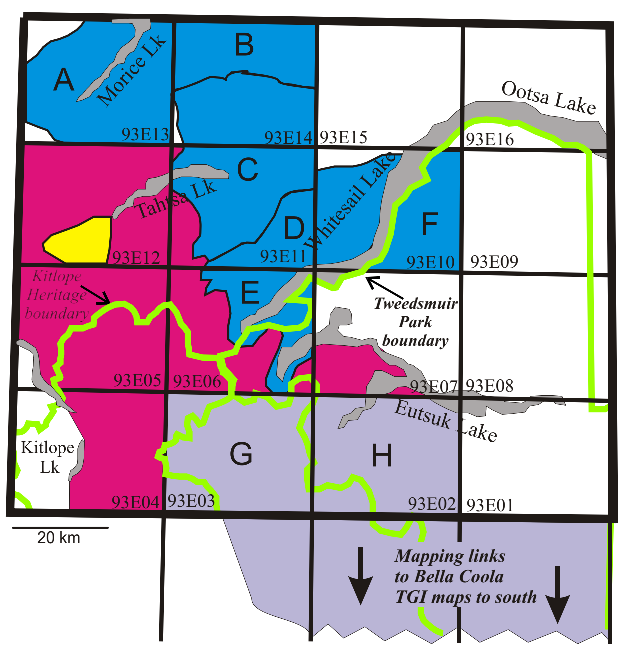

Figure 2. Geographic distribution of existing 1:50 000 geological maps in the Whitesail Lake map area, and the extent of mapping (red) conducted under the Geoscience BC program. Blue areas were mapped by BC Geological Survey teams (*ca.* 1985–1990; letters keyed to reference list); yellow area is thesis map of van der Heyden (1982); light purple area was mapped by Bella Coola Targeted Geoscience Initiative project in Bella Coola area (NTS 093D; 2001–2003), and NTS 093E/02 and 03 were mapped under the Rocks to Riches Program (2004).

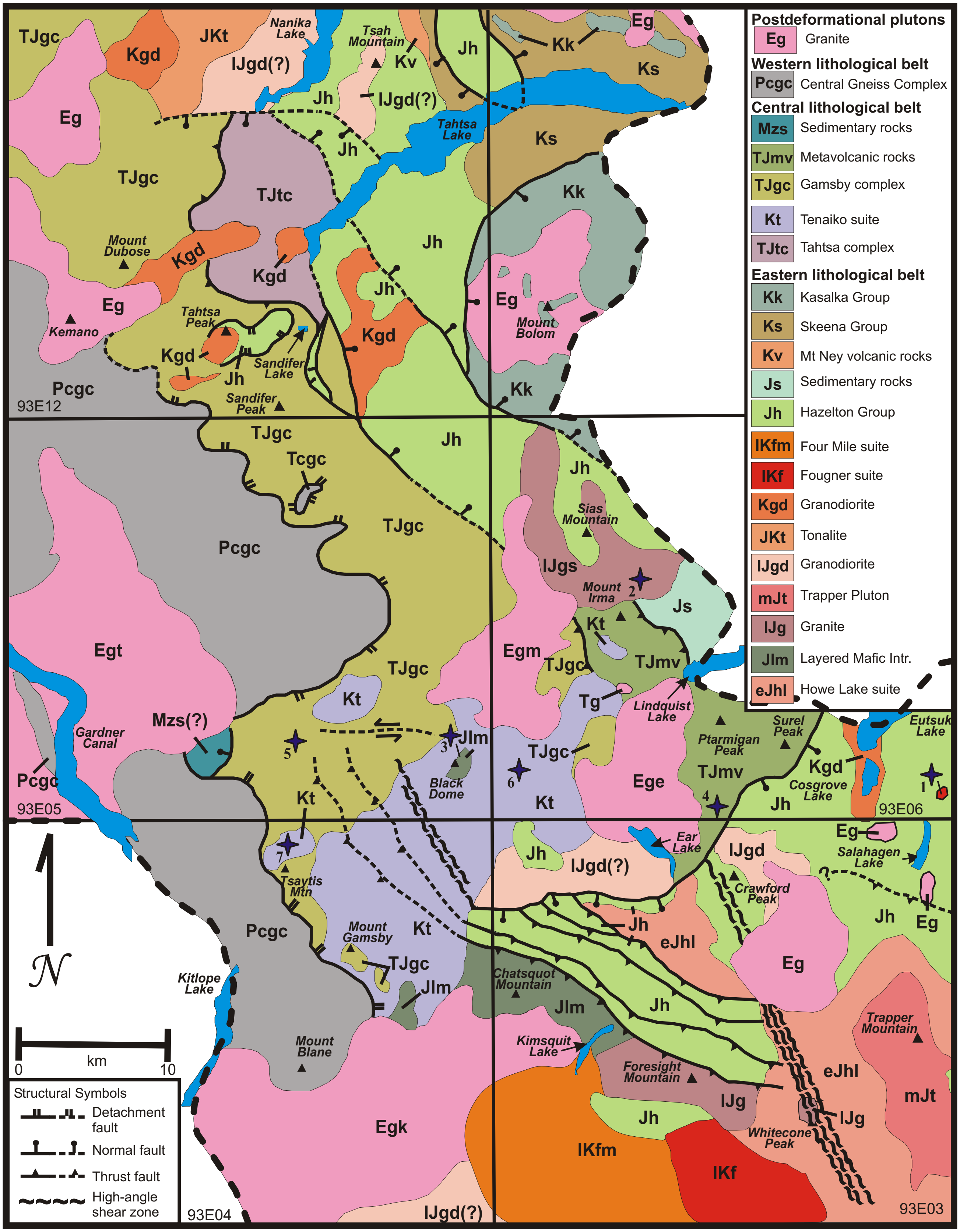

Figure 3. Generalized geology of the southwestern Whitesail Lake map area, showing major lithological units, structures and physiographic features referred to in the text. Plutons described in text are labelled: lJgs, Sias pluton; Egk, Kitlope pluton; Egt, Tsyatis pluton; Ege, Ear Lake pluton (Mahoney *et al.*, 2006); Egm, miarolitic granite pluton (Mahoney *et al.*, 2006). Blue stars indicate geochronological locations listed in Table 1.

TABLE 1. GEOCHRONOLOGICAL SAMPLE LOCATIONS, SOUTHERN AND WESTERN WHITESAIL LAKE AREA.

Map ID	Sample number	Easting	Northing	Map unit	Rock type	Location	Mean $^{206}Pb/^{238}U$	Method	Purpose
1	147aJBM04	633145	5807159	Eqm	Biotite-quartz monzonite	Red Bird Mtn	53.0 ± 0.3	TIMS	Dates Mo porphyry
2	HFB-05-94	609910	5913716	lJg	Granodiorite	Mt Irma N	146.3 ± 1.6	LA	Constrains TJmv + Js age
3	05-wv-50	597396	5905702	Jlm	Quartz diorite	Black Dome	187.5 ± 1.8	LA	Constrains Jlm age
4	HFB-05-52	614950	5900950	TJmv	Rhyolite breccia	Ear Lake N	170.28 ± 0.97	LA	Constrains TJmv protolith
5	05-RH-11	584274	5904955	TJgc	Metatonalite	NW Black Dome	206.0 ± 1.7	LA	Constrains TJgc protolith
6	HFB-05-53	603590	5901475	Jt	Hornblende quartz diorite	Tenaiko range	123.9 ± 1.6	LA	Dates Tenaiko suite
7	60JBM05	584601	5898393	Jt (?)	Epidote-biotite granodiorite	Tysatis Peak	125.50 ± 0.65	LA	Dates upper plate of the detachment

Abbreviations: LA, laser-ablation inductively coupled plasma mass spectrometry; TIMS, thermal ionization mass spectrometry

Creek–type volcanogenic massive sulphide mineralization (Gordee, 2005; Gordee *et al.*, 2005; Mahoney *et al.*, 2005). In that area, the Hazelton Group comprises a thick (>4 km), bimodal volcanic succession of basaltic and basaltic andesite flows and associated volcanogenic strata, interbedded with and overlain by rhyolitic tuff, lapilli tuff, tuff-breccia, tuffaceous sedimentary rocks and associated rhyolitic domes (Gordee, 2005; Gordee *et al.*, 2005). The stratigraphic position and composition of Middle Jurassic strata in the southern Whitesail Lake map area are very similar to the strata hosting the Eskay Creek VMS deposit. Although the strata were deposited in an actively extending environment favourable for the formation of VMS deposits, it is apparent that, in this region, these rocks were deposited in a shallow-marine setting that did not promote formation of such deposits (Gordee, 2005).

Structural, stratigraphic, geochronological and biostratigraphic data indicate that Hazelton Group strata in the Whitesail Lake map area occur in eastward-younging, gently east-dipping structural panels that become progressively older to the west, with deeper levels of the volcanic system exposed adjacent to the Coast Plutonic Complex (Gordee *et al.*, 2005; Mahoney *et al.*, 2005; Haggart *et al.*, 2006). In the southern and western portions of the map area, rocks assigned to the Hazelton Group occur in a discontinuous, northwesterly-trending structural panel east of the Central Gneiss Complex and associated metavolcanic rocks and west of extensive exposures of Cretaceous sedimentary and volcanic strata (Fig 3). Rocks herein mapped as Hazelton Group have previously assigned to the Lower Cretaceous Gambier Group (Woodsworth, 1980; Diakow, 2006). Lithological and stratigraphic similarities with rocks mapped as Hazelton Group (Gordee, 2005; Gordee *et al.*, 2005) to the south and new age constraints on crosscutting plutons (*see* description of Sias pluton, below) support inclusion of these strata in the Hazelton Group. The Hazelton Group comprises a thick succession of mafic volcanic flows, breccia, tuff-breccia and lapilli tuff, with lesser dark, thin-bedded, fine-grained argillite, siltstone and sandstone. Rhyolitic lapilli tuff, tuff and domes occur locally, but represent less than 20% of the main outcrop belt. Sedimentary strata intercalated with andesitic flows south of Price Peak yielded a poorly preserved ammonite and bivalve fossil assemblage of Late Pliensbachian to Toarcian age (Haggart, 2005), and U-Pb geochronology on other localities is in progress.

CHATSQUOT LAYERED MAFIC INTRUSION (UNIT Jlm)

Chatsquot Mountain and adjacent ridges contain spectacular exposures of a layered mafic intrusion (Jlm) that forms an important component of the regional volcanic stratigraphy. Compositional banding consists of variable proportions of olivine, pyroxene, plagioclase and magnetite, and ranges in composition from ultramafic magnetite-olivine websterite to anorthositic gabbro. The prominent foliation in the rock parallels the compositional layering and results in a distinctly layered appearance. Typical compositional layers are less than 1 m thick, with clinopyroxene-rich gabbro (80% clinopyroxene) alternating with more plagioclase-rich layers that distinctly weather to a lighter colour. Subordinate ultramafic layers include apparent cumulate layers of magnetite-olivine-rich rocks that weather to a distinctive rusty brown with knobbly surfaces. Along the ridge northeast of Chatsquot Mountain, unit Jlm is cut by numerous andesite porphyry dikes that locally exceed unit Jlm in volume and form intrusion breccia units. Unit Jlm extends from Chatsquot Mountain to the southern end of the Mount Gamsby ridge, and also caps the high peaks near Black Dome, where the layered mafic intrusion appears as a large screen within the Tenaiko intrusive suite (Fig 3).

The age of the Chatsquot layered mafic intrusion (LMI) is unclear. Two geochronological samples from anorthosite on Chatsquot Mountain and Gamsby Ridge were barren of zircons. A sample of undeformed quartz diorite collected from a succession of layered mafic intrusive rocks north of Black Dome yields a 187.5 ±1.8 Ma U-Pb zircon age. The quartz diorite is structurally concordant with layers within the LMI, and may represent a late-stage differentiate from the layered mafic system or, conversely, could be a younger sill. Therefore, this age is considered to provide a minimum age for the Chatsquot LMI.

JURASSIC (?) ARGILLITE AND SANDSTONE (UNIT Js)

A north to northeast-dipping, locally overturned panel of argillite, siltstone and sandstone underlies Lindquist

Peak, east of Mount Irma (Fig 3). The overall succession may be up to 2.5 km thick and consists of alternating units of argillite and sandstone, although portions of the section may be thrust repeated. Similar lithological facies comprise six sedimentary units, which include, in ascending order 1) a basal mixed sandstone and argillite package; 2) a massive, strongly foliated argillite package; 3) a dominantly massive sandstone package, with minor shale interbeds; 4) a dominantly argillaceous package, with minor interstratified sandstone; 5) a massive sandstone package, similar to unit 3; and 6) an upper mixed argillite and sandstone package.

Sedimentary structures include climbing ripple cross-stratification, flaser bedding and abundant bioturbation. Sandstone interbeds are locally micaceous. Wood fragments are abundant and bivalve moulds occur as shell lag deposits in a fine-grained, calcareous-cemented facies. The composition and sedimentary structures in this unit contrast strongly with those of volcanogenic strata of the Hazelton Group, and these rocks have been inferred to represent the base of the Jurassic–Cretaceous Bowser Lake Group in this region (Mahoney *et al.*, 2006). This stratigraphic assignment is supported by a new 146.3 ±1.6 Ma U-Pb zircon age on a crosscutting pluton (Fig 4, Table 1), which requires these strata to be Late Jurassic or older.

TRIASSIC (?) – JURASSIC METAVOLCANIC ROCKS (UNIT TJmv)

A succession of variably metamorphosed, mafic to silicic volcanic and volcaniclastic rocks, including andesitic to basaltic flows, tuff-breccia and tuff, with lesser argillite, is exposed west and south of Lindquist Lake. The metavolcanic rocks range from unfoliated to slightly foliated, thick bedded to massive, andesitic to rhyolitic lapilli tuff and tuff-breccia to strongly foliated tuff, sandstone and siltstone. The metamorphic grade varies from lower greenschist to upper greenschist, and chloritic schist (±epidote) dominates the package. A diagnostic characteristic of this package is that it contains readily identifiable volcanic textures with variable degrees of foliation, reflecting a strong rheological control during deformation. These rocks form a thrust panel structurally above unmetamorphosed Jurassic sedimentary rocks to the east (unit Js), and structurally beneath higher grade metavolcanic and metasedimentary rocks of the Gamsby complex (TJgc) to the west. These rocks occur along strike from unmetamorphosed to sub-greenschist Hazelton Group volcanic rocks, and a metamorphosed rhyolite breccia within the succession yielded a U-Pb zircon age of 170.3 ±0.97 Ma (Fig 4, Table 1), which is interpreted to constrain the age of the protolith, in part. The structural position, composition and age constraints suggest these rocks are metamorphosed equivalents of the Lower to Middle Jurassic Hazelton Group, based on their dominantly volcanic character and paucity of carbonate interbeds. The rocks appear to represent a metamorphic and structural transition between the more highly deformed and higher grade Gamsby complex and the Hazelton Group. It is therefore possible that the TJmv package includes Triassic (?) metavolcanic and metasedimentary components.

MOUNT NEY VOLCANIC ROCKS (?) (UNIT Kv)

East of Tsah Mountain, sparse outcrops containing fine-grained, dark green to black basalt flows with fresh, dark green augite phenocrysts and localized pillow structures overlie Jurassic Hazelton Group tuff-breccia and fine-grained volcaniclastic strata. These strata appear, in turn, to be overlain by feldspathic arenite and argillite of the Lower Cretaceous Skeena Group. Contacts in this area are not well exposed, but the overall stratigraphic succession appears to be a disconformable one. Lithological similarity and stratigraphic position suggest these rocks belong to unit lKv of MacIntyre (1985). Similar exposures are found just north of the Tahtsa Lake road, several kilometres southeast of Rhine Ridge and just east of the east end of Tahtsa Lake. Diakow (2006) informally referred to these strata as the Mount Ney volcanic rocks.

SKEENA GROUP (UNIT Ks)

A thick sequence of lithic feldspathic arenite and argillite is found in the northeastern part of the study area, the Rhine Ridge area and regions to the north, as well as the low country on the south side of Tahtsa Lake. Most of the succession dips very gently to the east. The base of the succession is not seen, although it appears to rest conformably (?) on the Mount Ney volcanic rocks approximately 5 km east of Tsah Mountain. The basal contact is interpreted to continue southward along strike to cross Tahtsa Lake where the Skeena Group appears to rest on Hazelton Group volcanic rocks. The unit is possibly overlain unconformably (?) by gently dipping to flat-lying Kasalka Group volcanic rocks on Rocky Ridge, although the precise nature of the contact, and whether or not it represents an unconformity, has not been established.

South of Tahtsa Lake, the lower part of the Skeena Group consists of approximately 350 m of mostly massive, fine to medium-grained feldspathic arenite. Individual sandstone beds within this lower part of the succession are up to several metres thick, locally show faint parallel laminations, and are intercalated with thinner, parallel-laminated mudstone or siltstone. Thin pebble lag horizons, including rounded to subangular, poorly sorted volcanic clasts and chert grains up to several centimetres in diameter, are noted uncommonly within the succession. The upper part of the Skeena Group is approximately 450 m in thickness, and consists of argillite with lesser sandstone beds of similar composition to those in the lower part of the succession. Wood fragments (up to several tens of centimetres in length) and leaf impressions are locally abundant.

In the Rhine Ridge area, the base of the section is not exposed, but the lower part of the succession consists of thick-bedded, fine to medium-grained sandstone with locally abundant ripple marks. Strata at this level of the section contain fossils assigned to the trigoniid bivalve *Myophorella* (*Steinmanella*) sp. (at UTM 608272E, 5955896N; Zone 9, NAD1983; identification by J.W. Haggart, specimens uncollected), suggesting a Valanginian (?) to Aptian age (Saul, 1978). The lower portion of the section is overlain by an argillitic section similar to that south of Tahtsa Lake, although this portion of the succession is significantly thinner in this area. Skeena Group rocks are considered to represent a range of shallow-marine to nonmarine depositional environments.

KASALKA GROUP (UNIT Kk)

North of Tahtsa Lake, the Upper Cretaceous Kasalka Group unconformably (?) overlies well-bedded arenite and argillite of the Skeena Group (Ks) and, to the south, forms a carapace on the Eocene Bollum stock (Fig 3; MacIntyre,

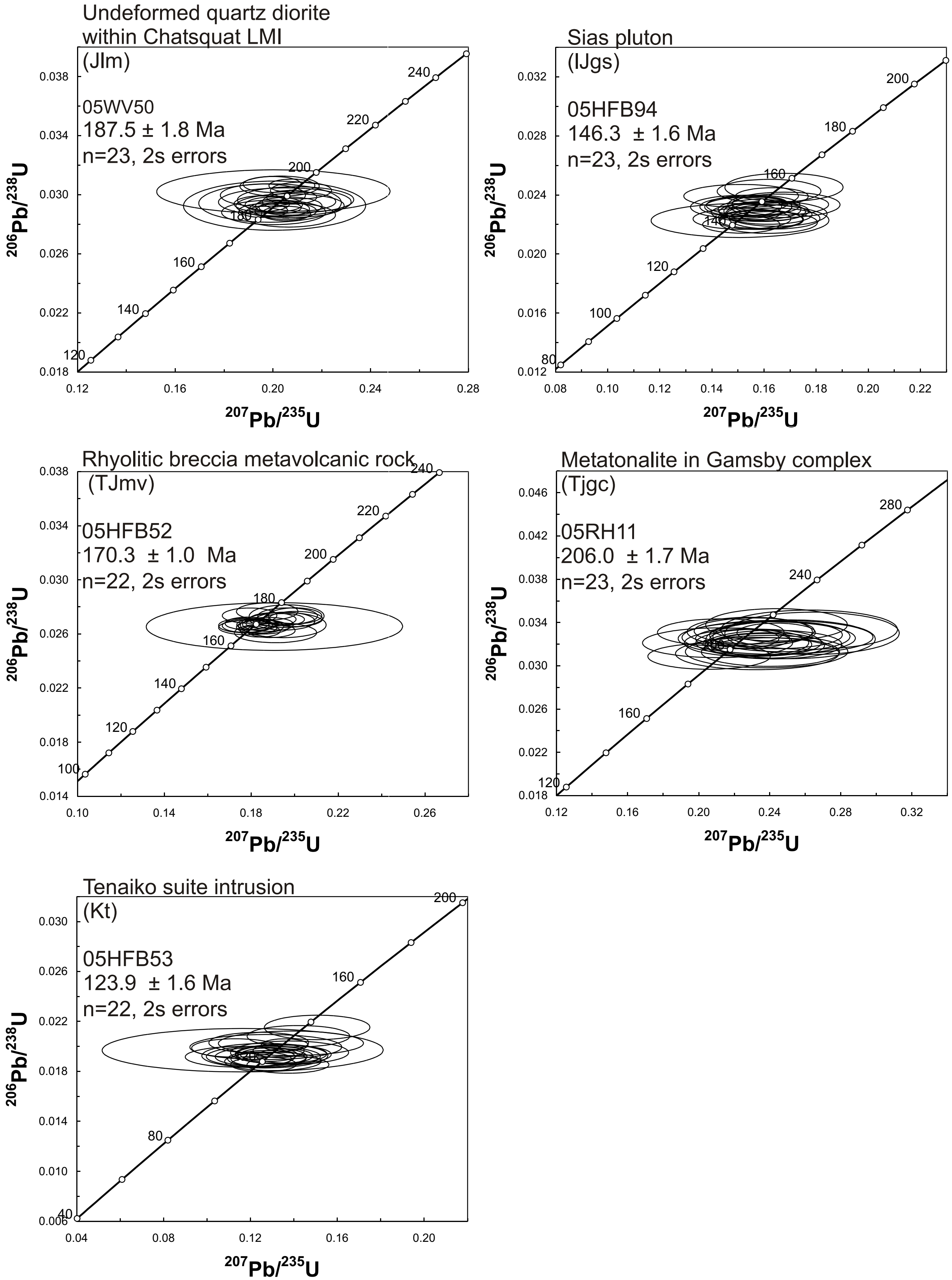

Figure 4. Standard concordia diagrams with U-Pb zircon data by laser ablation ICP-MS plotted at the 2σ confidence level; all interpreted ages are based on weighted averages of $^{206}Pb/^{238}U$ dates, also reported with 2σ errors; see text for discussion.

1985). On the western side of the outcrop belt, the base of the Kasalka Group is locally a spectacular buttress unconformity (?) displaying up to 10 m of relief between basal Kasalka Group boulder conglomerate containing 20 to 30% plutonic boulders (up to 1 m in diameter) and the underlying medium grey feldspathic arenite and dark grey argillite of the Skeena Group. To the east, the Kasalka Group – Skeena Group contact is far less prominent, represented by a basal felsic pebble conglomerate (<80% felsite pebbles) containing sparse Skeena Group rip-up clasts interbedded with feldspathic arenite and overlying the Skeena Group with less than a meter of erosional relief. The basal 200 m of the Kasalka Group consist of light grey-green felsic pebble conglomerate to dark red siltstone interbedded with dark red, primarily matrix-supported, pebble to cobble volcanic conglomerate that locally contains minor basalt flows. The proportion of primary basalt and basaltic andesite in the unit increases dramatically to the south near Mount Bollum. The Kasalka Group is easily distinguished from older Hazelton Group volcanic rocks by its essentially unaltered mineralogy and more heterogeneous conglomerate clast assemblage. A vertical feeder to the Kasalka Group extrusive volcanic rocks is seen intruding Hazelton Group andesitic volcanic rocks and volcanic sedimentary rocks on the northwest-trending ridge approximately 5 km east of Tsah Mountain. The feeder is roughly circular and approximately 150 m in diameter, and contains angular and fresh andesitic breccia fragments.

CENTRAL LITHOLOGICAL BELT

Gamsby Complex (Unit TJgc)

The central portion of the map area is underlain by a belt of imbricate structural panels of amphibolite, chloritic mafic metavolcanic rocks, and strongly foliated diorite, tonalite and granodiorite assigned to the Permian (?) to Jurassic Gamsby complex (Woodsworth, 1980). The Gamsby complex ranges in metamorphic grade from greenschist to lower amphibolite, locally to upper amphibolite, and there is a distinct decrease in metamorphic grade from west to east in this succession of metaplutonic and metavolcanic rocks (van der Heyden, 1982). This belt of rocks is flanked on the east by unmetamorphosed to weakly metamorphosed stratigraphic successions and on the west by the high-grade Central Gneiss Complex (Fig 3). The increased metamorphic grade and significantly higher proportion of metaplutonic rocks distinguish this succession from lower grade rocks to the east, and the presence of abundant chlorite distinguishes it from the Central Gneiss Complex to the west.

The Gamsby complex is composed primarily of strongly foliated chloritic schist, carbonaceous pelite, nondescript mafic to intermediate metavolcanic rocks, rhyolitic metatuff and lapilli tuff, with lesser quartzofeldspathic gneiss, amphibolite and micaceous schist. Felsic and intermediate dikes are common. Blue-grey, thin-bedded recrystallized carbonate forms a locally distinctive component (up to 30%; Fig 5). These rocks are complexly interleaved with pre and syndeformational metatonalite to granodiorite. Protomylonite and mylonite zones are common throughout the succession. Abundant quartz veining is common locally.

The unit is pervasively foliated, dominated by a very consistent, well-developed, northwest-trending foliation with locally abundant, tight to isoclinal, mesoscopic (5–25 cm amplitude) folds (Fig 5). Fold hinges are generally not dismembered, and fold limbs can be traced for several metres through a folded succession. These structures fold an earlier foliation, suggesting a polydeformational history.

The Gamsby complex is internally imbricated, with structural panels that interleave volcanic and plutonic rocks of different metamorphic grades. The Gamsby complex presumably represents a structural level intermediate between the Central Gneiss Complex to the west and lower grade rocks to the east. It forms the hangingwall of a major low-angle detachment structure that separates it from the underlying Central Gneiss Complex. On its eastern margin, the Gamsby complex is in thrust fault contact with lower grade rocks of the eastern belt. North of Tahtsa Peak, one of these west-dipping thrust faults places the Gamsby complex over the less deformed Tahtsa complex, and the fault is intruded by the Cretaceous Horetzky dike (Woodsworth, 1980; Stuart, 1960). The Gamsby complex therefore records evidence of pre-Cretaceous contractional deformation, which is overprinted by extension related to the uplift of the Central Gneiss Complex in Paleocene time (van der Heyden, 1982; Rusmore *et al.*, 2005).

Figure 5. A) Folded carbonate rocks in the Triassic–Jurassic Gamsby complex on ridge west of the Tsaytis River; carbonate interbeds have been sampled for micropaleontology. B) Foliated chloritic schist and discontinuous quartz segregations typical of the Gamsby complex.

The Gamsby complex contains a significant volume of metavolcanic and metaplutonic rocks, suggesting a probable volcanic arc setting. Geochemical analyses of metavolcanic rocks indicate a tholeiitic and calcalkaline volcanic arc origin (van der Heyden, 1982). The age of the volcanic protolith is probably Late Triassic to Early Jurassic, based on a 206.0 ±1.6 Ma U-Pb zircon age on a predeformational metatonalite east of Tsaytis Peak, and a poorly constrained *ca.* 210 Ma U-Pb age on a metarhyolite within the succession (van der Heyden, 1982). Additional geochronology is in progress. The abundance of carbonate lenses and beds within the complex also suggests a Triassic or Paleozoic age, at least in part.

WESTERN LITHOLOGICAL BELT

Central Gneiss Complex (Unit Tcgc)

The western lithological belt is defined by a distinctive sequence of strongly deformed upper amphibolite to granulite-facies quartzofeldspathic gneiss of the Central Gneiss Complex (Fig 3). The Central Gneiss Complex is a broad belt of high-grade metamorphic rocks that extends up the eastern edge of the Coast Plutonic Complex from about 53° to 56°N (Rusmore *et al.*, 2005). In the western Whitesail Lake map area, the Central Gneiss Complex is dominated by orthogneiss, including complexly interleaved quartzofeldspathic gneiss, hornblende-biotite tonalitic gneiss, amphibolitic gneiss and lesser amphibolite. Constituent minerals are very fresh and consist primarily of quartz, plagioclase, hornblende and biotite, with locally abundant garnet and epidote. Crosscutting foliated and nonfoliated biotite tonalite dikes are abundant, and migmatite zones are common. The complex is cut by numerous mylonitic shear zones. Ductile deformation fabrics, primarily mesoscale (0.5–1.5 m amplitude) tight to isoclinal folds and associated axial-planar foliation are common. Plutonic and metaplutonic rocks are widespread, including locally abundant foliated biotite tonalite, and syn to postdeformational K-feldspar-megacrystic granite and titanite-bearing granodiorite to tonalite.

PLUTONIC ASSEMBLAGES

Plutonic rocks are common throughout the western Whitesail Lake map area, and include Jurassic and Cretaceous diorite, granodiorite and tonalite, and Paleogene granodiorite and tonalite. There is no consistent age progression in the region, although Jurassic and Cretaceous plutons are concentrated between the western margin of the unmetamorphosed stratigraphic assemblages and the eastern edge of the Central Gneiss Complex, and Cenozoic plutons are most common in, but not restricted to, the Central Gneiss Complex. Plutons in the southwestern portion of the Whitesail Lake map area were described in Mahoney *et al.* (2006), so the following description focuses on the major plutonic bodies in the Tsaytis River (NTS 093E/5) and Tahtsa Lake (NTS 093E/12) 1:50 000 map areas.

Tahtsa Complex (Unit TJtc)

The name 'Tahtsa complex' was used by Stuart (1960) for a heterogeneous igneous complex of hornblende diorite and quartz diorite cut by quartz monzonite stocks and both granodiorite and mafic sills and dikes. The Tahtsa complex underlies a broad area west and north of the west end of Tahtsa Lake (Fig 3). The western margin of the complex is a low-angle, west-dipping thrust fault that places the Gamsby complex in the hangingwall over the Tahtsa complex in the footwall. The Tahtsa complex is in fault contact with the Hazelton Group along its eastern margin (Fig 3).

The Tahtsa complex is a heterogeneous assemblage of moderately foliated to nonfoliated, texturally variable, fine to coarse-grained hornblende diorite to quartz diorite (Fig 6). The complex is texturally and compositionally variable, with nonsystematic variations in grain size, mineral content, xenolith abundance, crosscutting dikes/dikelets and varying degrees of foliation. Importantly, the Tahtsa complex is not as pervasively deformed as the adjacent Gamsby complex. The rocks contain abundant xenoliths and screens of recrystallized pyroxene-bearing basaltic andesite and andesite, and are cut by abundant fine-grained felsic, intermediate and mafic dikes. The complex is intruded by numerous pods and stocks of undeformed coarse-grained granite. Rocks of the Tahtsa complex are predominantly lower greenschist grade, and locally upper greenschist to lower amphibolite grade.

The age of the Tahtsa complex is poorly constrained. It is cut by the Cretaceous (*ca.* 73 Ma) Horetzky dike (van der Heyden, 1982) and contains abundant metavolcanic screens that could represent stoped blocks of the Hazelton Group or Gamsby complex. Compositional similarities and spatial relations suggest the Tahtsa complex could be subvolcanic to the Hazelton Group, and therefore Early Jurassic in age. Geochronological analysis is underway.

Sias Pluton (Unit lJgs)

The Sias pluton is a homogeneous, medium to coarse-grained biotite-hornblende granodiorite to granite exposed near Sias Mountain. The pluton intrudes volcanic rocks of the Hazelton Group on its northern and western edges, and intrudes Triassic–Jurassic metavolcanic rocks (unit TJmv) and Jurassic (?) sedimentary rocks (unit J (?)s) along its southern boundary. It is itself intruded along its southwestern margin by miarolitic granite of the Gamsby River stock (Mahoney *et al.*, 2006). The pluton has a characteristically mottled green and pink colouration with distinctly green-tinted plagioclase, mottled green mafic minerals and dark

Figure 6. Heterolithic intrusive breccia and diorite and granodiorite dikes, showing multiple crosscutting relationships, typical of Tahtsa complex rocks.

pink potassium feldspar. This colour results from the presence of extensively chloritized biotite and hornblende, saussuritized plagioclase and dark pink interstitial and phenocrystic K-feldspar. Quartz, K-feldspar, chlorite and epidote veining is common. The body contains abundant hydrothermal breccia features, consisting of veins and pods of brecciated pluton fragments in a matrix of chlorite±epidote.

The Sias pluton is very similar to rocks of the Stick Pass plutonic suite mapped in the Bella Coola region to the south (Haggart *et al.*, 2006). This correlation is supported by a new 146.3 ±1.6 Ma U-Pb zircon date from the southern portion of the pluton (Fig 4, Table 1).

Tenaiko Suite (Unit Kt)

A heterogeneous assemblage of hornblende diorite to quartz diorite forms an extensive intrusive complex into the Gamsby complex, Chatsquot layered mafic intrusion and Hazelton Group between Mount Gamsby and Mount Irma in the southwestern portion of the Whitesail Lake map area. The Tenaiko suite is a compositionally and texturally heterogeneous intrusive suite that ranges from a coarse-grained pyroxene-hornblende gabbro to medium to coarse-grained hornblende diorite to quartz diorite with lesser hornblende granodiorite. The suite is characterized by complex intrusive relations with adjacent metavolcanic rocks and layered mafic intrusions, and contains locally abundant mafic and ultramafic xenoliths and metavolcanic screens, ranging from a few centimetres to tens of metres in length. The density of the inclusions is variable, ranging from isolated mafic xenoliths to dense intrusion breccia with distinctive interlocking jigsaw clast boundaries. Intrusive boundaries are highly irregular, with felsic stringers and dikelets invading adjacent country rock. The intrusive rocks are complexly foliated, locally displaying magmatic foliation surrounding entrained, structurally deformed metavolcanic screens and locally displaying syndeformational folds and postdeformational tectonic foliations.

The Tenaiko suite intrudes the Lower to Middle Jurassic Hazelton Group along its southern margin, is intruded by Paleogene granitoid plutons along its eastern margin and is cut by the Central Gneiss detachment fault along its western margin. The age of the suite is constrained by a new U-Pb zircon age of 123.9 ±1.6 Ma (Fig 4, Table 1), an Early Cretaceous age that is in agreement with a poorly constrained *ca.* 129 Ma U-Pb age on an unfoliated quartz diorite sample from the same body (van der Heyden, 1989).

Horetzky Dike (Unit Kgd)

The Horetzky dike was the name given by Stuart (1960) to a northeast-trending, elongate, medium-grained diorite and quartz diorite stock that occupies the drainage of Horetzky Creek (Fig 3). Other nearby bodies of similar composition are included within this unit. The principal body is medium grey in colour and is characterized by medium-grained, fresh, subhedral to euhedral hornblende; light grey to white subhedral plagioclase; and grey interstitial quartz. The mineralogy of the dike was described in detail by Stuart (1960). The dike is undeformed and has an unusual northeast-trending orientation that cuts northwest-trending contractional structures within the Tahtsa and Gamsby complexes. The age of the dike therefore provides a crucial constraint on contractional deformation in the region. Woodsworth (as reported in Diakow, 2006) obtained a 73.5 ±2.2 Ar/Ar biotite age on the Horetzky dike, which may or may not constrain the emplacement age. Uranium-lead zircon geochronology is underway.

Paleocene-Eocene Plutonic Rocks

KITLOPE PLUTON (UNIT Egk)

The Kitlope pluton is a massive, homogeneous biotite granite to granodiorite that intrudes the Central Gneiss Complex southeast of Kitlope Lake. The unit is characteristically medium to coarse grained and equigranular, but locally includes K-feldspar-porphyritic biotite granite with clean fresh books of biotite, white to pink K-feldspar, euhedral white plagioclase and large, anhedral quartz blebs. Oxidation of biotite leads to a distinct yellow weathering rind. The intrusive contact is generally sharp, with a locally well-developed intrusion breccia along the boundary. The Kitlope pluton clearly truncates the Central Gneiss detachment fault north of the Kitlope River drainage. Preliminary geochronological data suggest an Eocene age (M. Rusmore, pers comm to GJW, 2006).

TSAYTIS PLUTON (UNIT Egt)

The Tsaytis pluton was described by van der Heyden (1989) as a set of foliated tonalite sills, with foliation defined by aligned mafic minerals and stretched xenoliths along the pluton margins. Mapping east of Gardner Canal in the western portion of the Tsyatis River (093E/05) demonstrates that the Tsaytis pluton is composed primarily of syn to postkinematic K-feldspar-megacrystic biotite granite. The majority of the pluton is undeformed biotite granite that clearly truncates foliation within the Central Gneiss Complex but is locally foliated along the margins of the pluton. The pluton is elongate parallel to the dominant foliation trend in the Central Gneiss Complex, which suggests at least partial structural control on emplacement.

The unit is medium to coarse grained, characterized by fresh K-feldspar megacrysts (1–4 cm) within a matrix of brown euhedral biotite, white subhedral plagioclase feldspar and grey anhedral quartz. Intrusive contacts are generally sharp, but well-developed intrusion breccia is evident locally. The age of the pluton is not constrained, but must be Eocene or younger, based on the known age of the Central Gneiss Complex (Rusmore *et al.*, 2005). Van der Heyden (1989) reported a *ca.* 55 Ma U-Pb age, but it is unclear if this date is from the main K-feldspar-megacrystic phase of the pluton.

STRUCTURAL FEATURES

Central Gneiss Detachment

In the western Whitesail Lake map area, upper amphibolite to granulite facies rocks of the Central Gneiss Complex are separated from greenschist to lower amphibolite grade rocks of the Gamsby complex and Tenaiko suite by a low-angle, east-dipping detachment fault (Fig 7). In the lower plate, the Central Gneiss Complex is characterized by widespread quartzofeldspathic gneiss with well-developed foliation and abundant isoclinal folds, interleaved with fresh foliated to nonfoliated biotite tonalite. The majority of the upper plate contains chloritic, mafic to intermediate metavolcanic rocks and variably foliated diorite, tonalite and granodiorite of the Gamsby complex. The upper plate contains several imbricated structural panels of greenschist facies chloritic metavolcanic rocks, lower amphibolite facies metavolcanic rocks and metatonalite. The structural panels are apparently separated by steep, west-dipping faults of unknown displacement. These faults locally juxtapose amphibolitic metavolcanic rocks and metatonalite against greenschist facies metavolcanic-metaplutonic rocks; in other cases, the metamorphic transition appears more gradational.

These structurally interleaved panels increase in metamorphic grade from east to west, and the highest grade portion of the Gamsby complex in the hangingwall is commonly adjacent to the Central Gneiss Complex in the footwall, making the detachment fault difficult to locate precisely in the field. Locally, the detachment fault is readily recognized by a significant change in metamorphic grade, and by the abundance of chloritic rocks in the upper plate and the absence of chlorite in the lower plate. Elsewhere, the detachment fault does not appear to be a discrete structure, but rather a zone of interleaved panels of upper and lower plate rocks. The detachment fault is a very low angle structure, and may be partly crenulated, as suggested by the presence of at least one fenster east of the main detachment, where rocks of the lower plate project through, and are surrounded by, lower grade rocks of the upper plate (Fig 3).

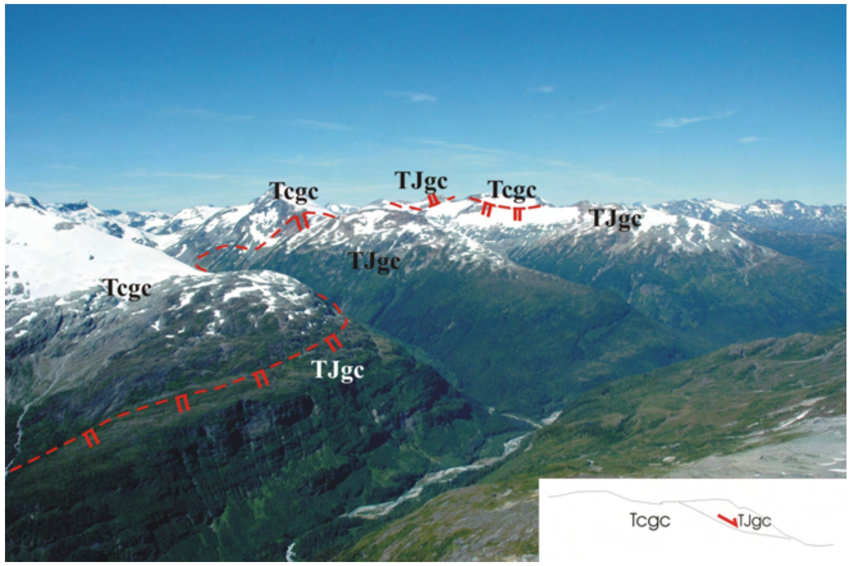

Figure 7. View to the west from the ridge east of the Tsaytis River drainage, highlighting the trace of the Central Gneiss detachment fault. Inset is a schematic cross-section, illustrating the relationship between the Gamsby complex (TJgc) and the Central Gneiss Complex (Tcgc).

Contractional Structures

In the southwestern portion of the Whitesail Lake map area, northeast of Chatsquot Mountain, various structural levels within the Hazelton Group are complexly imbricated in a stack of northeast-vergent thrust sheets (Mahoney *et al.*, 2006). A system of easterly-vergent imbricate thrust panels within the Gamsby complex was described by van der Heyden (1982). Mapping in the western Whitesail Lake map area documents a series of northwest-trending, east-vergent thrust faults that imbricate the Gamsby complex, Tahtsa complex, Tenaiko suite, Triassic–Jurassic metavolcanic rocks and the Hazelton Group. In general, there is a decrease in metamorphic grade from west to east, and the thrust system consists of imbricated panels of higher grade rocks structurally overlying lower grade rocks. This inverted metamorphic gradient was described by van der Heyden (1982), but a critical observation is that this east-vergent thrust system is restricted to the hangingwall of the Central Gneiss detachment. Geological mapping and structural analysis document distinctly different structural styles between lower plate and upper plate rocks, with the Central Gneiss Complex displaying a relatively uniform, northwest-trending fold-axis orientation, which contrasts markedly with the much more widely distributed orientations characteristic of folds in the Gamsby complex (Fig 8). The distinct difference in structural style suggests that the region has been subject to at least two structural episodes, an interpretation that is supported by mapping that demonstrates west-dipping faults that imbricate the Gamsby complex are cut by the unfoliated *ca.* 73 Ma Horetzky dike (Stuart, 1960; van der Heyden, 1989), whereas the Central Gneiss Complex includes pervasively foliated rocks as young as Paleocene (Rusmore *et al.*, 2005). We suggest the Gamsby complex was deformed in a pre–late Cretaceous deformational event, and the Central Gneiss Complex was produced by Paleocene deformation before their juxtaposition by thrust faults.

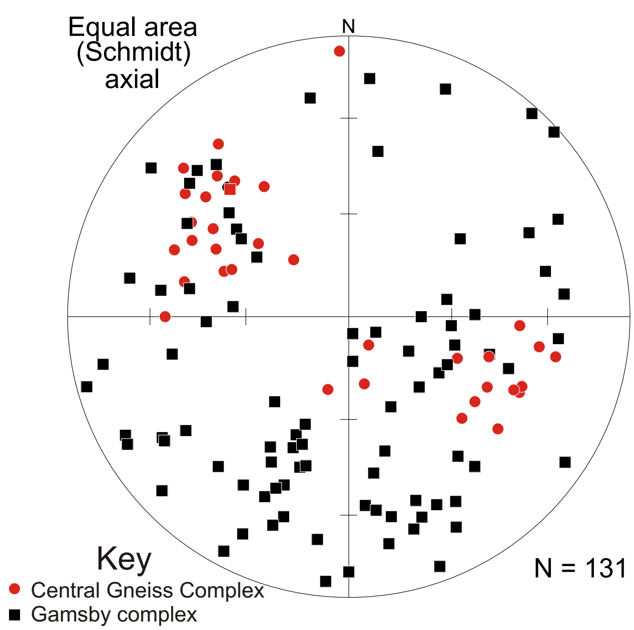

Figure 8. Stereonet of fold-axis orientations in the Gamsby complex (TJgc) and the Central Gneiss Complex (Tcgc) in the Tsaytis River (NTS 093E/05) and Tahtsa Peak (NTS 093E/12) 1:50 000 map areas.

Transcurrent Shear Zones

Several high-angle shear zones transect the area and cut all pre-Paleocene rock units. One of the larger shear zones parallels the Kimsquit River valley, extending north from the northern end of Dean Channel through Whitecone Peak and the western flank of Crawford Peak, where it is apparently truncated by a northeast-trending normal fault (Fig 3). The shear zone is characterized by pervasive near-vertical fracture planes and locally intense foliation development, manifested by mineral realignment and the stretching and reorientation of xenoliths and metamorphic screens. East of Crawford Peak, graphitic phyllite, chloritic schist and clastic metasedimentary and metavolcanic rocks are incorporated into the shear zone, and dextral transpression is indicated by the orientation of kink bands and vergence of isoclinal folds with moderately plunging (30–35°) fold axes (Mahoney *et al.*, 2005). A second prominent shear zone extends from Chatsquot Mountain northwest toward Black Dome. This shear system is approximately 1 to 1.5 km wide and consists of chloritic schist, micaceous schist, local actinolitic schist, foliated hornblende diorite and granodiorite, and pods of pyroxene gabbro that are crosscut by syndeformational andesitic to basaltic dikes. The shear zone is characterized by northwest-trending foliation containing prominent, moderately northwest-plunging intersection and mineral-elongation lineations. The shear zone is flanked on both sides by the Tenaiko suite, suggesting a lack of major offset along the system. The shear zone is truncated at its southern end by a high-angle normal fault that separates it from the Chatsquot layered mafic intrusion. The presence of high-angle shear zones at both ends of the thrust system suggests that the thrust system may represent a contractional step-over at a restraining bend along a dextral transpressional system (Mahoney *et al.*, 2005, 2006).

The northern portion of the map area contains several significant northwest-trending, generally steeply east-dipping normal faults that juxtapose different structural and metamorphic levels. Many of these high-angle structures appear to be brittle faults, but several display penetrative fabrics and may have accommodated strike-slip translation of unknown magnitude.

ECONOMIC POTENTIAL

The primary objective of this investigation is a comprehensive evaluation of the economic mineralization potential in the western and southwestern Whitesail Lake map area. Known mineral occurrences (MINFILE, 2006), stream sediment geochemistry (Lefebure and Gunning, 1988) and regional bedrock mapping suggest that the area may hold potential for volcanogenic massive sulphide, Cu±Mo±Au porphyry and Ni-Cu-Cr-PGE (platinum group element) mineralization. Detailed geological mapping and systematic geochemistry, geochronology, petrology and economic mineral evaluation studies are assessing the distribution of, and controls on, potential economic mineralization in the region. Bedrock geological mapping and preliminary geochemical data suggest that there are several potential targets of economic importance.

Volcanogenic Massive Sulphide Deposits Within the Hazelton Group

Lower to Middle Jurassic strata of the Hazelton Group in the southern Whitesail Lake map area are strikingly similar to strata hosting the Eskay Creek volcanogenic massive sulphide (VMS) deposit in northern British Columbia. Detailed mapping, volcanic facies analysis, geochronology and geochemistry of Hazelton Group strata demonstrate the lithological, age, compositional and stratigraphic similarities between these rocks and Eskay Creek strata, and document predominantly shallow-water deposition in an extensional volcanic arc environment (Gordee, 2005). The similarities between these strata and those in the Eskay Creek area suggest that the Hazelton Group in the Whitesail Lake map area is also prospective for VMS mineralization. Despite these similarities, no direct evidence of VMS-style mineralization has been discovered beyond stratiform pyritic horizons, and it is likely that the shallow-marine depositional setting of Hazelton Group rocks in the southern Whitesail Lake map area was not favourable for deposition of volcanogenic massive sulphides (Gordee, 2005).

Rhyolitic volcanic rocks of the Hazelton Group in the southern Whitesail Lake map area are near the top of a homoclinal, eastward-dipping stratigraphic sequence that becomes progressively older to the west, with deeper levels of the volcanic system exposed in the southwestern and western portions of the study area. Here, rocks assigned to the Hazelton Group contain a higher proportion of mafic volcanic flows and associated breccia, tuff-breccia, lapilli tuff, and tuff, as well as intervals of dark, thin-bedded, fine-grained argillite, siltstone and sandstone. Rhyolitic tuff-breccia, lapilli tuff, tuff and domes form a minor, yet ubiquitous, portion of the section. Hazelton Group rocks contain locally abundant sulphide-bearing (pyrite, minor chalcopyrite) quartz-siderite veins, particularly adjacent to crosscutting plutons, and commonly contain disseminated pyrite associated with rhyolitic tuff and dikes. In addition, the Hazelton Group probably represents, in part, the protolith for the Triassic–Jurassic metavolcanic sequence and the Gamsby complex, and these units may therefore have potential for both VMS and postdepositional vein-type mineralization.

Chatsquot Layered Mafic Intrusion

The Chatsquot layered mafic intrusion has previously been inferred to have potential for significant Cu-Ni sulphide and PGE mineralization (Mahoney *et al.*, 2006). Pyroxene-rich compositional layers (clinopyroxene gabbro) locally contain visible coarse-grained chalcopyrite (or Cu-Ni sulphide) mineralization, which occurs as disseminated stratiform sulphides and sulphide veins. Preliminary geochemical results from unmineralized gabbro bodies indicate elevated metal values (*e.g.*, >0.35% Cu, >600 ppm Ni, >0.20% Cr). Although initial PGE assays are not particularly encouraging, additional detailed stratigraphic and geochemical analysis may be beneficial.

Cu±Mo±Au Porphyry Mineralization

Paleocene and Eocene plutonic rocks in the southwestern Whitesail Lake map area are generally coarse-grained, locally porphyritic granitic rocks that were apparently emplaced at relatively shallow levels. Intrusive contacts with adjacent country rock are generally sharp, although extensive (tens of metres) zones of locally mineralized intrusive breccia occur locally, and there is evidence of sulphide (primarily Cu and Mo) remobilization along some intrusive boundaries (Mahoney *et al.*, 2006). Geochemical and geochronological studies of these plutons are underway, and assay samples collected from alteration zones adjacent to pluton margins have been submitted.

Fault-Controlled Mineralization

The Central Gneiss detachment fault represents an important surface for potential economic mineralization. The high-grade gneiss and associated foliated to nonfoliated plutonic and metaplutonic rocks of the Central Gneiss Complex in the footwall do not contain economic mineralization, apparently due to the high temperature of formation. However, low-grade metamorphic rocks in the hangingwall are cut by several generations of faults and shear zones, which locally display structurally controlled, sulphide-bearing (pyrite, chalcopyrite) vein mineralization. Chloritic schist and metavolcanic rocks of the Triassic–Jurassic metavolcanic rocks (unit TJmv) and the Gamsby complex are cut by both brittle and ductile structures with associated quartz-siderite veins, which locally display both disseminated and vein pyrite-chalcopyrite mineralization (Fig 9). Dioritic plutonic rocks of the Tahtsa complex are cut by discrete brittle faults that host similar mineralization. Fault-parallel, tan to pink quartz-siderite veins with locally abundant pyrite and chalcopyrite are common; siderite veins are commonly cut by quartz-rich veins and display open space, comb and cockscomb textures containing coarse (4–5 mm) euhedral pyrite. These structures are readily identified by ubiquitous iron staining and locally well-developed malachite staining, and small gossans are common in the area, particularly adjacent to crosscutting plutons. Initial assay results indicate locally elevated metal values in the metavolcanic package (unit TJmv; >20.7% Cu, >2.7 ppm Au, >270 ppm Ag; Fig 9) and the Tahtsa complex (>1.7% Pb, >0.12% Ag, >0.8% Zn). Additional assays from these units and the Gamsby complex are underway.

Just south of Mount Irma, an approximately 1 km wide, low-angle, southwest-dipping shear zone deforms Triassic–Jurassic metavolcanic rocks trending southwards to Lindquist Pass. Metavolcanic rocks consist primarily of feldspar-phyric meta-andesite, andesite breccia and basalt, with lesser associated metadiorite. The metavolcanic package northeast of this zone is relatively undeformed, whereas rocks to the southwest are strongly foliated, schistose and chloritic, with locally extensive epidote stockwork and clots, and siliceous veining. The shear zone is the locus of numerous quartz and biotite-phyric rhyolitic dikes, swarms and plugs, oriented subparallel to the shear zone fabric; dikes are inferred to be of Eocene age. A few dikes also intrude the relatively undeformed metavolcanic rocks exposed northeast of the shear zone. Dikes vary in width from several tens of decimetres up to several tens of metres and commonly brecciate associated country rock; several dikes are traceable for 1 to 2 km. The rhyolitic intrusive activity is associated with prominent sulphide mineralization, developed in siliceous quartz-rich veins within the shear zone and also disseminated in adjacent country rock (Park and Peacock MINFILE occurrences). Quartz veins show pervasive pyrite-chalcopyrite-malachite-bornite mineralization (Fig 9). Pyrite is typically angular and coarse (2–3 mm), and developed in open framework within quartz veins; associated bornite is also localized in quartz veins, and is typically fine to medium-grained (1–2 mm). Geochemical assays are in process.

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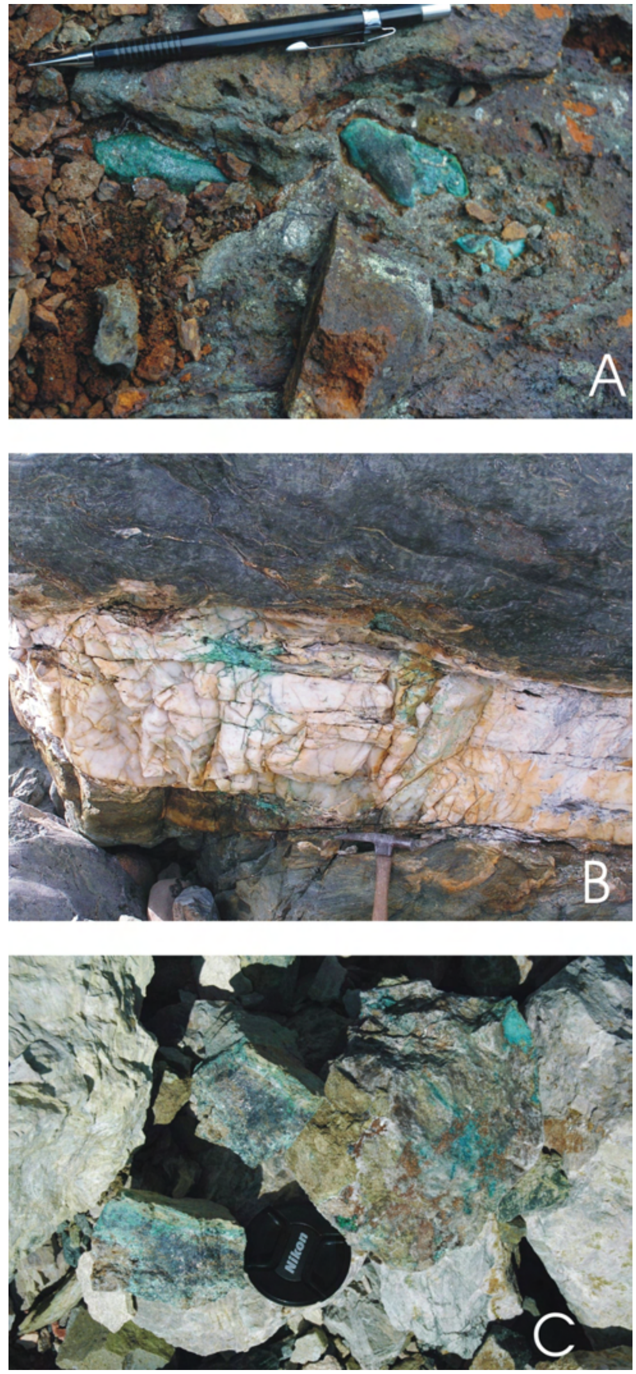

Figure 9. A) Mineralized shear zone within unit TJmv; fault gouge contains thick (2–3 cm) veins of massive pyrite and lesser chalcopyrite (foreground); breccia clasts within fault zone are pervasively copper stained. B) massive (30–35 cm) hydrothermal quartz vein with copper staining along margins cutting chloritic schist of the Gamsby complex; these quartz veins locally brecciate country rock and contain disseminated pyrite±chalcopyrite. C) Pyrite-chalcopyrite-malachite-bornite mineralization in quartz veins within shear zone in unit TJmv, near Mount Irma.

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