Geology of the Kutcho assemblage between Kutcho Creek and the Tucho River, northern British Columbia (NTS 104I/01)

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KEYWORDS: Kutcho assemblage, Cache Creek terrane, King Salmon fault, Nahlin fault, Kutcho fault, Kutcho Creek volcanogenic massive sulphide deposit

INTRODUCTION

The Kutcho project is a two-year bedrock mapping program initiated by the British Columbia Geological Survey Branch in 2010. The aim of the project is to gain a better understanding of, and provide more detailed geological maps for, the Permo-Triassic Kutcho assemblage, which hosts the Kutcho Creek volcanogenic massive sulphide deposit. The study is part of the Edges (Multiple Metals-Northwest Canadian Cordillera (Yukon, British Columbia)) project, which is a contribution to the GEM (Geomapping for Energy and Minerals) program. This program was initiated by the Federal Government in 2008 to enhance public geoscience knowledge in northern Canada, in order to stimulate economic activity in the energy and mineral sectors.

This report summarizes preliminary results from the first year's fieldwork on the Kutcho project. Fieldwork was conducted over seven weeks (July 2-28; August 12 - September 2) by a single traverse team comprising the author and student assistant Scott Caldwell (University of Victoria). Work was conducted from Kutcho Copper Corporation's exploration camp on Kutcho Creek. Operating funds were provided by the British Columbia Geological Survey, a private-public partnership agreement with Kutcho Copper Corporation, the Geological Survey of Canada (Edges project) and a partnership agreement with the University of Victoria.

The 2010 map area covers about 200 square kilometres and encompasses the main exposure belt of the Kutcho assemblage, between Kutcho Creek and the Tucho River, including the Kutcho Creek Cu-Zn volcanogenic massive sulphide occurrence (MINFILE 104I 060). It is located in the southeast corner of NTS map sheet 104I (Cry Lake) and encompasses the transition between the Stikine Ranges of the Cassiar Mountains to the north and the Spatsizi Plateau to the south. The nearest community is Dease Lake, located on Highway 37, 100 km west-northwest of the Kutcho Creek deposit. A poor tote road connects the map area to Dease Lake, but the most efficient access is by air, facilitated by a gravel airstrip at the exploration camp on the west side of Kutcho Creek.

This publication is also available, free of charge, as colour digital files in Adobe Acrobat® PDF format from the BC Ministry of Forests, Mines and Lands website at http://www.empr.gov.bc.ca/Mining/Geoscience/PublicationsCatalogue/Fieldwork.

PREVIOUS WORK

Geological studies by the Geological Survey of Canada in the Cry Lake and Dease Lake map areas, carried out intermittently from 1956 to 1991, are summarized in the report and 1:250 000-scale geological maps of Gabrielse (1998). This work incorporates regional studies of the Kutcho assemblage by Monger (1977), Monger and Thorstad (1978), Thorstad (1979, 1984) and Thorstad and Gabrielse (1986), as well as studies carried out in the immediate vicinity of Kutcho Creek deposit by provincial government geologists from 1974 to 1977 (Panteleyev, 1975, 1978; Pearson and Panteleyev, 1976; Panteleyev and Pearson, 1977a, b).

The Kutcho Creek massive sulphide deposit, discovered in 1973, was described by Bridge *et al.* (1986) after more than a decade of exploration, including 292 drillholes, by Esso Minerals Canada and Sumitomo Metal Mining Co. More recently, the deposit and host rocks were described by Barrett *et al.* (1996), who document details of primary and alteration geochemistry. A concurrent study by Childe and Thompson (1997) presents U-Pb radiometric dates and radiogenic isotope characteristics of the Kutcho assemblage.

REGIONAL GEOLOGICAL SETTING

The geological setting of the Kutcho Creek – Tucho River map area is shown on Figure 1. The map area is located at the east end of the King Salmon allochthon, a relatively narrow structural/stratigraphic belt that has been traced several hundred kilometres to the west-northwest, and separates the main exposures of the oceanic Cache Creek terrane to the north from those of the Stikine arc terrane to the south. The allochthon itself consists mainly of Early to Middle Jurassic clastic sedimentary rocks of the Inklin Formation, which forms the main exposure belt of the Whitehorse trough in northern British Columbia. Older rocks that are preserved locally in the eastern part of the allochthon include bimodal volcanic and volcaniclastic rocks of the Kutcho assemblage, as well as narrow lenses of oceanic rock (basalt, chert, serpentinite)

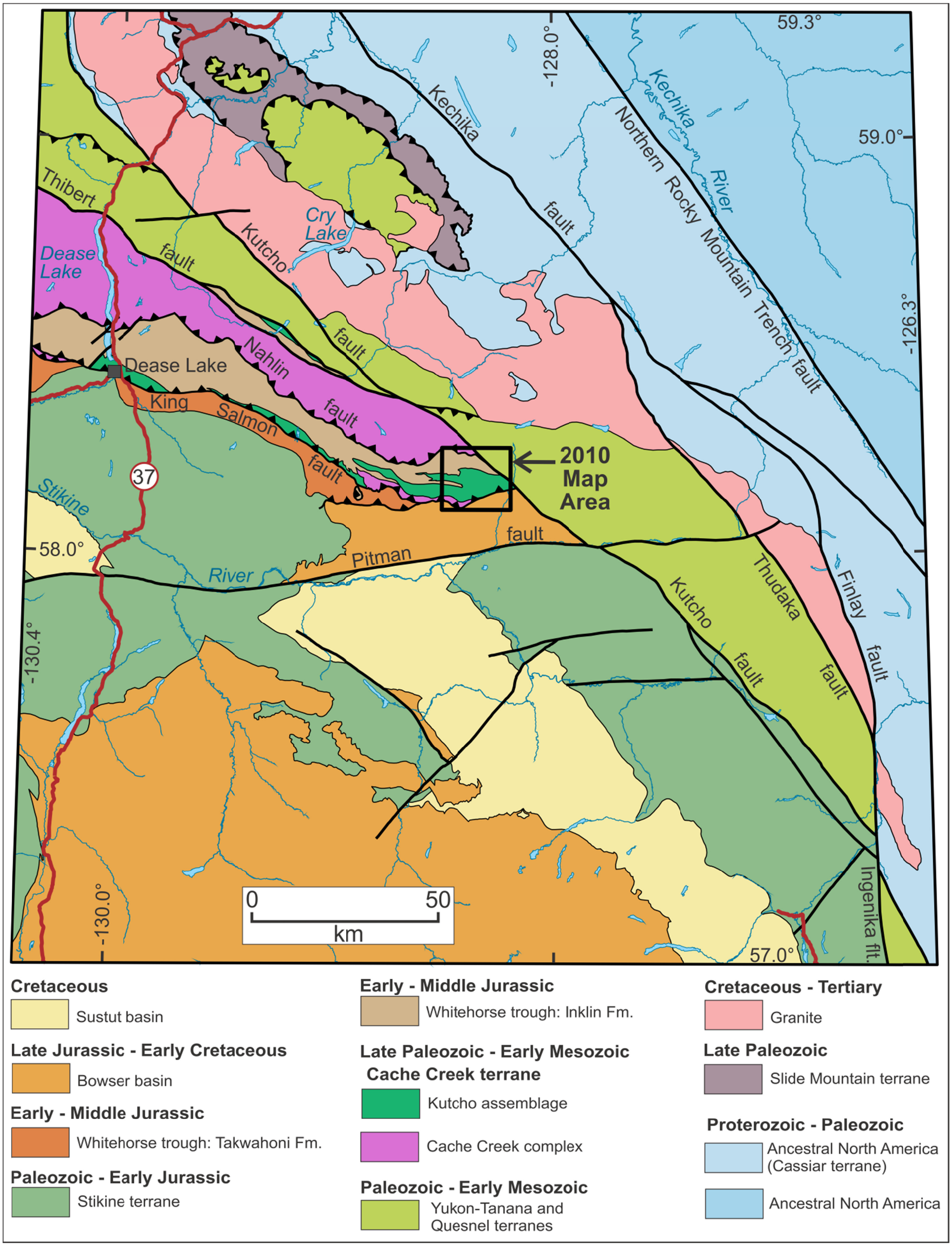

Figure 1. Regional geological setting of the 2010 map area, after Massey *et al.* (2005).

that have been included in Cache Creek terrane (Gabrielse, 1998). The King Salmon allochthon is bounded by the King Salmon and Nahlin faults, which are interpreted as northerly dipping thrust faults that were active in early Middle Jurassic time.

The King Salmon allochthon, together with adjacent Cache Creek and Stikine terranes, is truncated to the northeast by a system of northwest-striking faults that record significant dextral strike-slip displacement of Cretaceous and Tertiary age (Gabrielse, 1985, 1998; Gabrielse *et al.*, 2006). The fault panels directly northeast of the Cache Creek – King Salmon – Stikine belts include mid-Paleozoic, late Paleozoic and Mesozoic arc sequences that are part of Yukon-Tanana and Quesnel terranes (Gabrielse, 1991; Nelson and Friedman, 2004). Farther northeast, these rocks are faulted against, and intruded by, a major belt of granitic rocks that includes the Cretaceous Cassiar Batholith. The rocks northeast of this granitic belt consist mainly of Proterozoic through Paleozoic sedimentary rocks of North American affinity, locally overlain by thrust slices of oceanic Slide Mountain terrane, Quesnel terrane and Yukon-Tanana terrane, which together comprise the Sylvester allochthon (Gabrielse, 1991; Nelson and Friedman, 2004).

GEOLOGICAL UNITS

The distribution of the main geological units within the 2010 map area is shown on Figure 2, and a schematic vertical cross-section through the western part of the area is shown on Figure 3. Most units are part of the King Salmon allochthon, which includes the Permo-Triassic Kutcho assemblage, together with a structurally underlying unit of mainly metabasalt and serpentinite assigned to the Cache Creek Complex, and a Triassic-Jurassic metasedimentary succession that overlies the Kutcho assemblage across an erosional unconformity. The latter succession includes a local conglomerate unit containing clasts derived from the Kutcho assemblage, and overlying limestone, slate, siltstone and sandstone correlated with the regionally extensive Late Triassic Sinwa and Early to Middle Jurassic Inklin formations. All map units within the allochthon are deformed by south-verging folds, with an associated axial planar cleavage defined by greenschist facies mineral assemblages. The allochthon is bounded to the south by the north dipping King Salmon thrust fault, and to the north by the Nahlin fault. Jurassic chert-pebble conglomerate of the Bowser Lake Group occurs in the footwall of the King Salmon fault, and serpentinized ultramafic rocks of the Cache Creek terrane crop out on the north side of the Nahlin fault. The northwest striking Kutcho fault truncates the King Salmon allochthon near the northeast edge of the map area, and juxtaposes it against undated plutonic rocks, mainly granodiorite and quartz diorite, which are part of the Quesnel terrane. The youngest unit mapped in the area is a small post-metamorphic plug of diorite that cuts the Kutcho assemblage in the southwest part of the map area. This plug, and abundant sills and dikes of hornblende-pyroxene-plagioclase porphyry that are too small to be shown on Figure 2, are probably Eocene in age.

Cache Creek Complex within the King Salmon allochthon

Metabasalt and related rocks that occur at the base of the King Salmon allochthon in the southwest part of the map area are assigned to the Cache Creek Complex. These rocks rest structurally above the Bowser Lake Group across the King Salmon fault, and are in turn overlain by the basal part of the Kutcho assemblage across a suspected fault contact. They pinch out to the east, within the current map area, but have been traced as a continuous belt for 25 km to the west of the area (Gabrielse, 1998).

The Cache Creek Complex in the southwestern part of the map area is dominated by metabasalt, but also includes minor amounts of bedded chert, limestone and gabbro, and includes substantial amounts of serpentinite along the structural base and top of the succession. The fine-grained metabasalt is medium to pale green, weakly to strongly schistose, and typically forms monotonous greenish brown to rusty brown weathered exposures that show little or no indication of original mineralogy or texture. Vague pillow outlines occur locally, and fragmental schist, containing light greenish grey epidote altered feldspathic fragments and dark green chloritic fragments, was noted in one area about 2 km south-southeast of peak 2075. Thin sections of typical metabasalt reveal a foliated metamorphic assemblage of mainly actinolite, chlorite and epidote, with partial preservation of an original groundmass comprising intergrown clinopyroxene and plagioclase, as well as rare clinopyroxene microphenocrysts.

Fine and medium grained chlorite-epidote-plagioclase semischists, derived from diabasic and gabbroic rocks, respectively, were noted at two widely-spaced locations within the southern Cache Creek Complex, and may represent sills or dikes within the compositionally similar metabasalt. Medium grey to brownish grey bedded chert, comprising chert beds 1-4 cm thick separated by chloritic partings, forms an interval about 10 m thick that is intercalated with metabasalt just west of peak 1667. Similar chert, and light grey weathered limestone, occur as lenses between the metabasalt and structurally underlying serpentinite, about 300 m southwest of the peak. The serpentinite forms the structural base of the Cache Creek Complex, and rests above chert-pebble conglomerate of the Bowser Lake Group across the unexposed trace of the King Salmon fault. Serpentinite also occurs at the structural top of the Cache Creek Complex, directly beneath unit KS1 of the Kutcho assemblage, and commonly encloses lenses of silicified metabasalt and chert.

The rocks described above are readily included in the Cache Creek Complex on the basis of lithology. They are

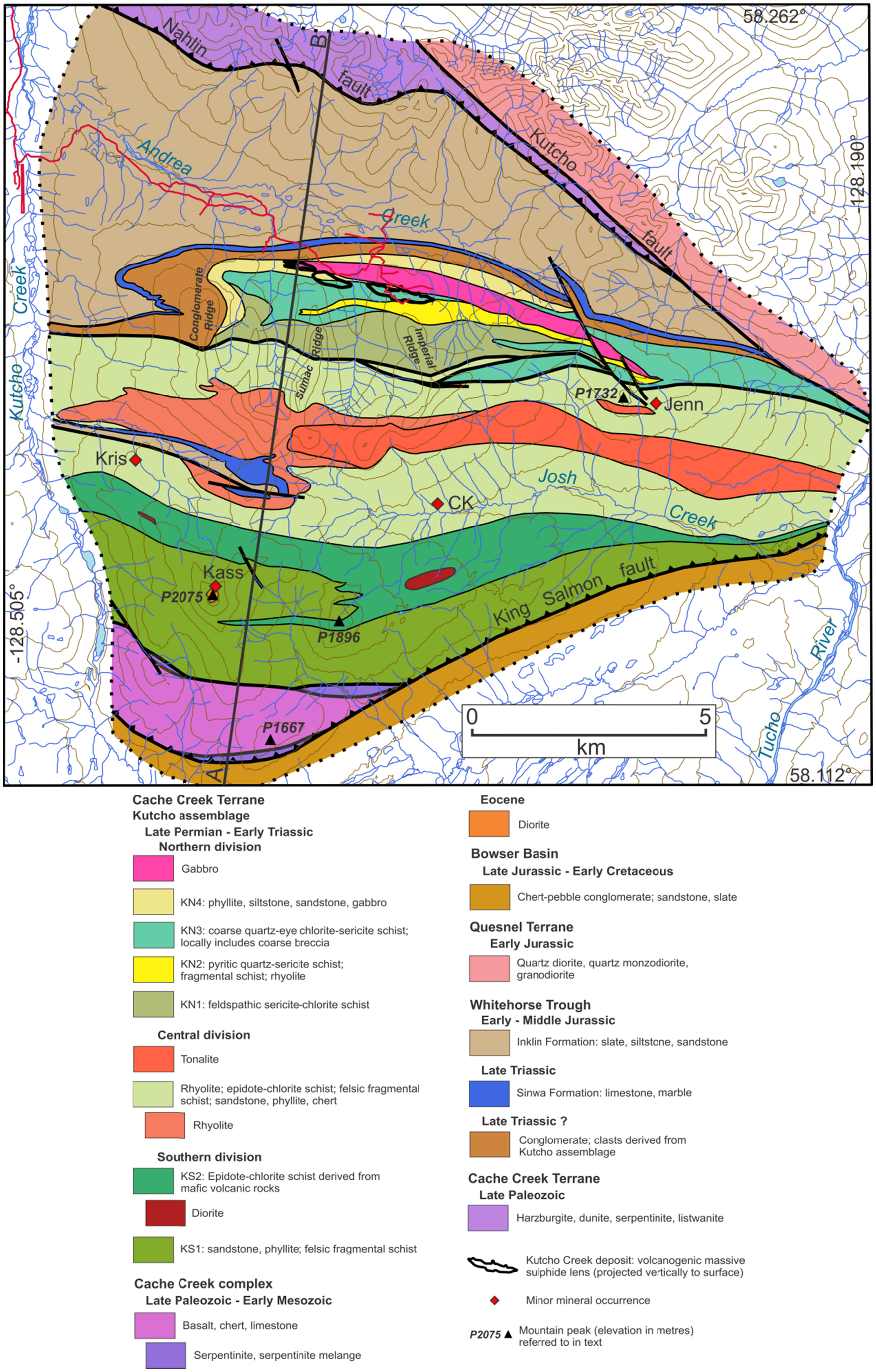

Figure 2. Generalized geology of the Kutcho Creek – Tucho River map area, based mainly on 2010 fieldwork.

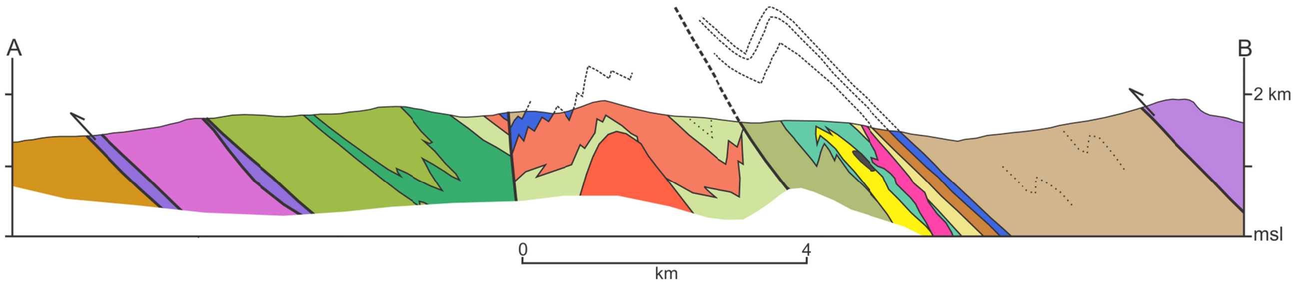

Figure 3. Schematic vertical cross-section along line A-B in Figure 2. See Figure 2 for legend.

not dated, but chert and limestone samples collected during the 2010 field season are currently being processed for microfossils.

Kutcho assemblage

The Kutcho assemblage is a heterogeneous package of schists derived from felsic and mafic volcanic and volcaniclastic rocks and associated felsic and mafic intrusions. The widest belt of exposures, and the informal type area for the assemblage, is within the current map area (Thorstad and Gabrielse, 1986). This belt continues for about 25 km to the west of Kutcho Creek, and the assemblage is also represented by several smaller lenses that have been mapped within the King Salmon allochthon as far west as Dease Lake (Gabrielse, 1998).

Gabrielse (1962) included rocks presently assigned to the Kutcho assemblage in a diverse map unit, of Devono-Mississippian and possibly younger age, that also contained adjacent rocks currently assigned to the Cache Creek Complex. Rocks of the Kutcho assemblage caught the attention of exploration and government geologists with the discovery of the Kutcho Creek Cu-Zn volcanogenic massive sulphide deposit in 1973. The rocks in the vicinity of the deposit were described by Panteleyev (1975) and Pearson and Panteleyev (1976), and were correlated with the Late Paleozoic Asitka Group of the Stikine terrane by Panteleyev and Pearson (1977b) and Monger (1977), on the basis of lithologic similarity and an Early Permian Rb-Sr isochron date of 275 ±15 Ma. Monger and Thorstad (1978) referred to these rocks as the Kutcho sequence and, together with Panteleyev (1978), suggested that they might be Triassic, based on the apparent intercalation of Kutcho felsic schists with Triassic limestone assigned to the Sinwa Formation on the west side of Kutcho Creek. Thorstad (1979, 1984) and Thorstad and Gabrielse (1986) referred to these rocks as the Kutcho Formation, and assigned them a Late Triassic age, based in part on a Rb-Sr isochron date of 210 ±10 Ma that was considered to be more robust than the Early Permian date quoted by Panteleyev and Pearson (1977b).

Childe and Thompson (1997) introduced the term assemblage, rather than formation, for the Kutcho rocks, and presented U-Pb zircon radiometric dates that established an Early Triassic age for the upper part of the assemblage. They obtained a date of 242 ±1 Ma from rocks directly above the Kutcho Creek deposit, a date of 246 +7/-5 Ma from rocks in the footwall of the deposit, and a date of 244 ±6 Ma from a quartz-plagioclase porphyry dike to the south of the deposit. Childe and Thompson (1997) also obtained primitive Nd isotopic signatures from Kutcho volcanic rocks and primitive Pb isotopic signatures from the syngenetic mineralization of the Kutcho Creek volcanogenic massive sulphide deposit. These data, together with geochemical data presented by Barrett *et al.* (1996), showing that mafic and felsic volcanic rocks from the Kutcho assemblage have a tholeiitic affinity, with depleted high field-strength elements and flat to LREE-depleted REE patterns, indicate that the Kutcho assemblage formed in an intra-oceanic arc environment.

The Kutcho assemblage within the 2010 map area is subdivided into 3 divisions referred to as southern, central and northern. Although there are local fold repetitions, the assemblage generally dips and faces to the north, such that the southern division includes the structural base of the assemblage and the northern division includes the highest stratigraphic units within the assemblage. However, the structural relationship between the central and northern divisions is not well understood, and they may in part be laterally equivalent.

SOUTHERN DIVISION

The southern division of the Kutcho assemblage comprises two mappable units. Unit KS1 includes phyllite, siltstone and sandstone that form the base of the assemblage, together with overlying schists derived mainly from felsic volcaniclastic rocks. Unit KS2 overlies and interfingers with unit KS1, and consists of schists derived mainly from mafic volcanic rocks.

Unit KS1

The basal part of unit KS1 comprises up to a few tens of metres of dark grey phyllite and calcareous phyllite, intercalated with intervals of laminated siltstone and phyllitic limestone, and thin to medium beds of schisty sandstone and gritty sandstone (Figure 4). The gritty sandstone contains plagioclase, quartz and pale grey felsic lithic fragments, within a recrystallized matrix of fine grained, foliated sericite, chlorite, quartz and plagioclase, locally with significant amounts of calcite and epidote. It becomes predominant in the upper part of the basal

Figure 4. Thin-bedded sandstone, siltstone and phyllite, basal part of unit KS1, southwestern part of the map area.

Figure 6. Graded gritty sandstone bed, unit KS1, 700 m southeast of peak 1896.

section, and passes upwards into a thick interval of fragmental schists that form the dominant rock type within unit KS1. These fragmental schists are typically medium to dark green, and weather to a pale brownish green colour. They comprise flattened, commonly epidote altered lithic fragments and plagioclase grains within a well-foliated matrix that contains variable proportions of chlorite, sericite, quartz, plagioclase, calcite and epidote, and locally actinolite or stilpnomelane (Figure 5). The lithic fragments are typically a few millimetres to a few centimetres in size, but coarser units, with lithic clasts up to 10 cm in longest dimension, occur locally. The fragments are dominated by aphanitic to very fine grained felsite, locally with small feldspar and/or quartz phenocrysts. Fragments composed of fine grained, equigranular intergrowths of feldspar and quartz are also present, and one exposure, 1.5 km east of peak 1896, includes a substantial number of medium grained quartz monzonite clasts. The fragmental schists commonly display a crude stratification, and in places occur as distinct thin to thick beds, some of which are graded (Figure 6). The stratification is enhanced locally by intercalations of thin bedded medium green chlorite-sericite schist with relict sand-size grains of quartz and

Figure 5. Felsic fragmental schist, unit KS1, 1 km south of peak 2075.

plagioclase, or medium to dark grey laminated phyllite and siltstone.

In the western part of the map area, the uppermost part of unit KS1 is dominated by relatively fine grained, commonly thin bedded to laminated schists comprised of well-foliated quartz, plagioclase, sericite, chlorite, epidote and calcite, locally with biotite or stilpnomelane, commonly containing relict silt to sand-size grains of quartz and plagioclase. These rocks, derived from felsic tuffs and/or epiclastic rocks, are intercalated with compositionally similar schists and semischists derived from coherent felsic volcanic rocks, with porphyritic textures defined by scattered phenocrysts of plagioclase±quartz.

A sill of medium grained melanocratic hornblende-pyroxene gabbro cuts fragmental schists of unit KS1 about 1 km east of peak 1896. The sill locally displays a weak foliation and is suspected to be broadly related to the Kutcho assemblage. It may be part of a magmatic system that fed overlying mafic metavolcanic rocks of unit KS2.

Unit KS2

Unit KS2 consists mainly of chlorite-epidote schist derived from mafic volcanic and volcaniclastic rocks. The mafic schists overlie, and interfinger with, the felsic schists of unit KS1, and locally include narrow units of similar felsic schist, as well as units of chlorite-epidote-feldspar schist derived from dioritic intrusive rocks.

The predominant rock type of unit KS2 is medium to dark green, greenish brown weathered, calcareous epidote-chlorite schist that commonly has a laminated appearance due to the segregation of metamorphic minerals into alternating chlorite-rich and calcite-epidote-rich layers (Figure 7). Relict feldspar grains are conspicuous in many exposures, and blebs of dark green chlorite, 2-4 mm across, that may have been derived from pyroxene phenocrysts were observed in an exposure 500 m north of peak 1896. This exposure also features small vesicles, suggesting that these schists were derived from

Figure 7. Plagioclase-epidote-chlorite schist, unit KS2, 2 km northwest of peak 2075.

weakly vesicular flows. Elsewhere, protolith textures are obscure, although fragmental schist, with epidote-altered fragments several centimetres in size, occurs locally, and may have been derived from pillow or flow breccia. Thin sections of typical schist comprise thoroughly recrystallized calcite-epidote-chlorite-plagioclase, with traces of quartz and sericite.

Dioritic rocks, with a relict medium grained, equigranular texture of intergrown plagioclase and altered mafic minerals, were noted at several localities within unit KS2, and locally form sill-like bodies up to several tens of metres wide. A thin section from one of these metadiorite units comprises relict plagioclase grains interspersed with a metamorphic assemblage dominated by epidote, actinolite, chlorite and calcite.

Quartz-plagioclase-sericite schists, derived from felsic volcanic and volcaniclastic rocks, are scattered throughout unit KS2, but are a relatively minor component and typically form narrow units less than 10 m wide. Some are porphyritic rocks, derived from flows, sills or dikes, which contain relict phenocrysts of plagioclase and/or quartz. Others are derived from tuffs or epiclastic rocks, and contain small felsic lithic fragments as well as relict crystals of quartz and plagioclase. One felsic dike that cuts mafic schists 500 m north of peak 1896 comprises fine grained, equigranular hornblende-biotite tonalite.

CENTRAL DIVISION

The central division of the Kutcho assemblage is a heterogeneous succession that includes large amounts of coherent metarhyolite, as well as epidote-chlorite schists derived from mafic volcanic rocks, fragmental schists derived from felsic volcaniclastic rocks, and bedded metasedimentary intervals that include sandstone, siltstone, phyllite and chert. Metarhyolite forms a large mappable unit in the west-central part of the unit, but most of the components are intercalated on too fine a scale to be separated out on Figure 2. Tonalite forms a large sill-like intrusion in the central part of the division, and two smaller bodies farther north. Small bodies of metadiorite are also present, but are not sufficiently large to be shown on Figure 2.

Mafic metavolcanic rocks form dark green, brownish-weathered units that range from a few metres to several tens of metres thick. They consist of variably calcareous actinolite-epidote-chlorite-plagioclase schists that display little of their original mineralogy or texture, although epidote-rich amygdules are preserved locally, and hints of pillows were noted in a few exposures. Small bodies of metadiorite are associated with the mafic metavolcanic rocks locally, and are recognized by a relict medium grained, equigranular texture of plagioclase intergrown with mafic grains that are now altered to actinolite, epidote and chlorite.

Metarhyolite units range from a few metres to several hundreds of metres thick, and probably include flows, sills and dikes. They are typically light grey to greenish grey, weakly foliated rocks that display conspicuous phenocrysts, 1-4 mm in size, of quartz and plagioclase, within a very fine-grained groundmass of quartz, plagioclase and scattered flakes of sericite (Figure 8). Relict flow banding was noted at a few localities, and breccia zones comprising metarhyolite fragments within a similar metarhyolite matrix, occur locally. Some narrow units, and the margins of some thicker units, are strongly foliated quartz-sericite schists with flattened phenocrysts. Metarhyolite typically forms tabular concordant units intercalated with all other major components of the central division. Locally, however, it occurs as irregular dikes that crosscut some mafic metavolcanic units. The large mappable metarhyolite body is probably a composite flow-dome unit. It displays considerable variation with respect to amounts, proportions and size of quartz and feldspar phenocrysts, and several internal breccia zones, but does not include significant intercalations of mafic metavolcanic or metasedimentary rocks.

Fragmental schists within the central division consist of flattened, pale grey to green felsic volcanic clasts, and

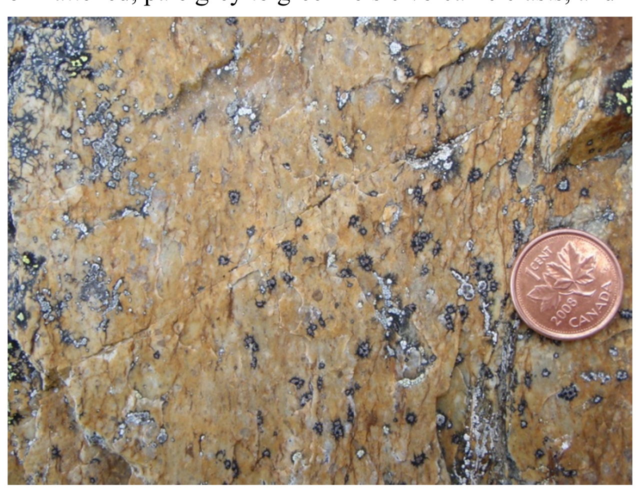

Figure 8. Quartz-feldspar phyric metarhyolite, central division of the Kutcho assemblage, Sumac ridge.

grains of plagioclase and quartz, within a foliated matrix of fine-grained chlorite, sericite, plagioclase and quartz (Figure 9). These occur as poorly stratified units that were probably derived from felsic tuffs or mass-flow deposits, as well as thick beds intercalated with finer grained metasedimentary rocks. Locally, fragmental schists are derived from the brecciated margins of coherent metarhyolite units.

Intervals of well bedded metasedimentary rocks, from a few metres to several tens of metres thick, are fairly common within the central division of the Kutcho assemblage, particularly within the northern, stratigraphically higher parts of the division. The metasedimentary rocks are commonly represented by narrow intervals of thin bedded, dark grey to greenish grey phyllite, siliceous phyllite, chert and siltstone (Figure 10). Thicker sections include thin to thick beds of fine to coarse-grained sandstone and granule conglomerate that contain feldspar, quartz and felsic lithic fragments. Pale grey to greenish grey bedded chert, comprising thin chert beds separated by thinner interbeds and partings of siliceous phyllite, locally dominates intervals up to 20 m thick. Chert also occurs as massive to vaguely laminated layers up to several metres thick that may have been derived from siliceous exhalites.

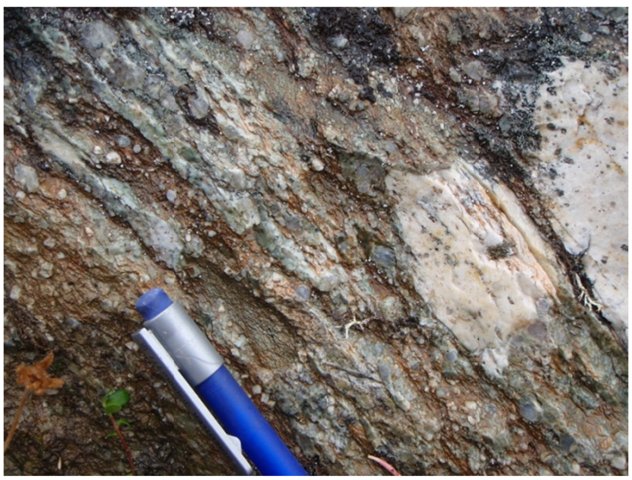

Figure 9. Felsic fragmental schist, central division of the Kutcho assemblage, south end of Conglomerate ridge.

Figure 10. Thin-bedded phyllite, siliceous phyllite and chert, central division of the Kutcho assemblage, Sumac ridge.

Tonalite

Tonalite forms a large elongate pluton, up to 1 km wide and more than 10 km long, within the central part of the central division of the Kutcho assemblage. Two smaller tonalite bodies are mapped to the north of the main body, and narrow dikes or sills of tonalite were noted at a few localities elsewhere in the division. The tonalite typically forms blocky, light grey-weathered exposures. It is characterized by a medium grained, equigranular texture of intergrown quartz and plagioclase, but some sections are coarse grained, with quartz grains and aggregates more than 1 cm in size (Figure 11). Primary mafic minerals are not preserved, but clots of chlorite-epidote comprise 5 to 20% of the rock. A weak to moderate foliation is displayed locally, and is defined by anastomosing seams of sericite and chlorite that enclose partially shredded grains of relict quartz and feldspar and, locally, small titanite grains.

NORTHERN DIVISION

The northern division of the Kutcho assemblage consists mainly of chlorite-sericite schists that contain variable proportions of quartz and feldspar crystals and felsic lithic fragments. These rocks were derived from felsic tuffs, flows and related epiclastic deposits. They are subdivided into 3 units, KN1, KN2 and KN3, on the basis of the types and proportions of the crystal and lithic fragments they contain. The uppermost unit within the division, KN4, consists mainly of thin bedded volcanic sandstone, siltstone and phyllite. A thick gabbroic sill is mappable within the northern division, and dikes and sills of similar composition are common within unit KN4.

Unit KN1

Unit KN1 comprises feldspar and quartz-bearing schists derived mainly from crystal-rich tuffs. It forms the base of the northern Kutcho division in the area south of

Figure 11. Tonalite, from main tonalite body that cuts the central division of the Kutcho assemblage, 800 m south of peak 1732.

the Kutcho Creek deposit, where it underlies unit KN2, which hosts the massive sulphide lenses. It thins to the east, where it becomes stratigraphically or structurally interleaved with a belt of rocks assigned to unit KN3, and was not recognized in the area northwest of peak 1732.

The schists of unit KN1 are medium green on fresh surfaces and typically weather to a grey-green or brownish green colour. They are characterized by conspicuous grains of plagioclase, typically 1-4 mm in size, which are invariably accompanied by quartz grains of similar or smaller size, and locally by quartzofeldspathic and/or epidote altered lithic grains, 2-10 mm in size (Figure 12). The plagioclase typically forms whole or broken crystals with subhedral shapes. The quartz crystals commonly display embayed margins, and locally include granophyric intergrowths of plagioclase. The relict mineral and lithic grains typically form more than 50% of the rock, and are enclosed in a fine grained, well-foliated matrix of chlorite, sericite, quartz and plagioclase, locally with significant amounts of epidote and carbonate. The schists are for the most part not conspicuously stratified, but locally they are intercalated with narrow intervals of thin-bedded schist of similar composition but finer grain size.

Figure 12. Sericite-chlorite schist with plagioclase and quartz grains, unit KN1, Imperial ridge.

Figure 13. Rusty weathered quartz-sericite schist, unit KN2, 3 km northwest of peak 1732.

Unit KN2

Unit KN2 comprises fissile, variably pyritic quartz-sericite schists and fragmental schists that comprise the hydrothermally altered footwall to the Kutcho Creek massive sulphide lenses. The unit is referred to as the footwall lapilli tuff by Bridge *et al.* (1986) and Barrett *et al.* (1996). It has been traced about 5 km eastward from the Kutcho Creek deposit, to the area north of peak 1732.

Unit KN2 consists mainly of pale grey to greenish grey, very fissile quartz-sericite schist that commonly weathers rusty due to the presence of disseminated pyrite and flattened porphyroblasts of Fe-Mg carbonate (Figure 13). Small grains of quartz are common, as are flattened lithic fragments, up to a few centimetres long, of pale grey siliceous felsite, with or without small phenocrysts of quartz. Narrow lenses of quartz-plagioclase phyric metarhyolite, derived from flows, sills or dikes, were noted locally. They comprise about 25% quartz and plagioclase phenocrysts, 2-4 mm in size, within a very fine grained, weakly foliated groundmass of quartz, plagioclase and sericite.

Unit KN3

Unit KN3 is a distinctive unit characterized by coarse quartz grains. It occurs stratigraphically above the Kutcho Creek massive sulphide lenses, where it is referred to as hangingwall quartz-feldspar crystal tuff (QFCT) by Bridge *et al.* (1986), and QFCT rhyolite by Barrett *et al.* (1996). This belt can be traced into the eastern part of the map area, but is partially obscured by the gabbro sill. A belt of similar rocks forms the south margin of the northern division east of Imperial ridge. It is suspected that this belt is a fault bounded repetition of the hangingwall belt, although there appears to be some stratigraphic interfingering with unit KN1. The northern and southern belts of unit KN3 apparently merge farther to the east, to form a single wide belt that forms most or all of the northern Kutcho division in the eastern part of the map area. If the southern belt is, in fact, largely fault bounded, then this wide belt northeast of peak 1732 probably includes one or more fault repetitions.

Unit KN3 consists primarily of medium to pale green or silvery green schists that contain abundant glassy quartz eyes, typically 2-10 mm in size, but locally to 1.5 cm, as well as smaller plagioclase grains, typically 1-5 mm in size (Figure 14). The quartz crystals are highly strained and commonly have embayed margins. The plagioclase grains are variably altered to sericite and/or epidote, and commonly have subhedral or euhedral outlines. In a few exposures the crystal grains are accompanied by sparse quartzofeldspathic lithic fragments, up to 3 cm in size. The large crystal grains commonly form 20-40% of the rock, and are enveloped by a matrix that consists mainly of fine grained, well-foliated quartz, plagioclase sericite and chlorite. There is little evidence for stratification or internal contacts within

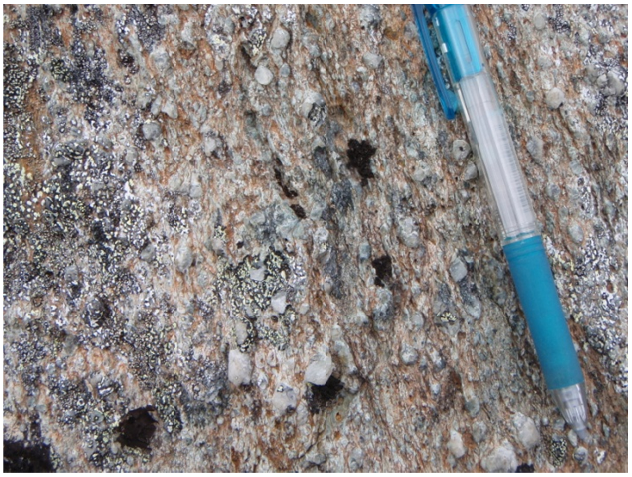

Figure 14. Coarse quartz-eye schist, unit KN3, north end of Imperial ridge.

the unit, despite the fact that there is considerable variation in the abundance and proportions of crystal grains, as well as sericite versus chlorite content of the foliated matrix. However, Bridge *et al.* (1986) report that drillholes in the vicinity of the Esso massive sulphide lens have intersected thick graded beds in the upper part of the unit.

A lens of coarse matrix-supported breccia, at least several tens of metres wide, is exposed within the upper part of unit KN3 at the north end of Sumac ridge. The matrix consists of coarse quartz-eye schist typical of the unit, and the vast majority of the clasts, which range up to 30 cm in size, are the same rock type (Figure 15). The clast population also includes a minor proportion of fine to medium grained equigranular quartzofeldspathic rock, and rare mafic clasts of calcareous epidote-chlorite schist. Parts of the breccia unit display hints of a crude stratification, and lenses of laminated coarse grained quartz-feldspar sandstone are intercalated with coarse breccia units locally (Barrett *et al.*, 1996).

The schists of unit KN3 are clearly derived from rhyolitic volcanic or volcaniclastic rocks, but it is not generally obvious whether the protolith was coherent porphyritic flows, tuffs or epiclastic rocks. Barrett *et al.* (1996) suggest that the unit is derived mainly from crystal rich pyroclastic flows with lesser block and ash flows, locally reworked as high density debris flows.

Figure 15. Breccia, unit KN3, north end of Sumac ridge.

Unit KN4

Unit KN4, comprising siltstone, sandstone and phyllite, is the uppermost unit of the Kutcho assemblage within the map area. It is underlain mainly by coarse quartz-eye schists of unit KN3, and is overlain by the conglomerate unit. Unit KN4 is cut by the main gabbro sill, and includes numerous thinner sills and dikes of gabbro.

Unit KN4 is equivalent to the tuff-argillite unit of Bridge *et al.* (1986) and Childe and Thompson (1997), and the argillite-siltstone unit of Barrett *et al.* (1996). It is not well exposed, and a large proportion of the few available outcrops are dominated by gabbroic sills and dikes that intrude the metasedimentary rocks of the unit. Where exposed, the metasedimentary succession includes grey, brownish grey weathered, well bedded schisty sandstone, vaguely laminated grey-green phyllitic siltstone to fine-grained sandstone, and grey phyllite to silty phyllite. The schisty sandstone ranges from coarse to fine grained and occurs as thin to medium, locally graded beds (Figure 16). Detrital grains are mainly feldspar and quartz, but coarse sandstone and gritty sandstone beds also contain flattened chips of quartz-feldspar-sericite phyllite, probably derived from felsic lithic grains, and blebs of biotite-chlorite that may have been derived from mafic mineral or lithic grains. A thin section from a fine-grained sandstone unit consists of well-foliated quartz-plagioclase-sericite-biotite, with minor chlorite and calcite, which preserves little of its original clastic texture.

Gabbro

Gabbro forms a thick body, up to 500 m wide in map-view, which has been traced for about 8 km within the northern division of the Kutcho assemblage. Although its three-dimensional orientation and true thickness are

Figure 16. Graded sandstone beds, unit KN4, northeast of Kutcho Creek massive sulphide deposits.

not well constrained, it has the appearance of a transgressive sill that gradually cuts upsection from east to west. Similar gabbro is common as dikes and sills within unit KN4, and has also been reported as narrow dikes in felsic schists lower in the section (Childe and Thompson, 1997).

The gabbro is dark green on fresh surfaces and typically forms blocky, grey-green or brownish green weathered exposures. Relict crystals of randomly-oriented plagioclase, commonly up to 1 cm, and locally to several centimetres in size, are conspicuous in most exposures. Relict hornblende grains may also be present, but the mafic component has largely been replaced by a weakly to moderately foliated metamorphic assemblage dominated by epidote, biotite, actinolite, chlorite and calcite. Sericite is also common, typically as an alteration mineral within the relict plagioclase grains, and minor amounts of apatite occur as small relict grains.

The gabbro unit cuts the uppermost part of the northern Kutcho division, including post-volcanic sedimentary rocks of unit KN4, and it has a chemical signature that is distinct from mafic metavolcanic rocks elsewhere within the Kutcho assemblage (Barrett *et al.*, 1996; Childe and Thompson, 1997). It may, therefore, be unrelated to the volcanic and plutonic rocks of the Kutcho assemblage. However, Childe and Thompson (1997) suggest that the gabbro is not significantly younger, because gabbro units display peperitic textures where they contact metasedimentary rocks of unit KN4, and interaction zones where they contact underlying felsic metavolcanic rocks, suggesting that these units had not been completely lithified when they were intruded by the gabbro.

Conglomerate unit

The conglomerate unit forms a single belt that has been traced across the north-central part of the map area, where it is underlain by the Kutcho assemblage and overlain by the Sinwa Formation. It has long been recognized as a distinct map unit, but has been variably interpreted as either part of the Kutcho assemblage (Bridge *et al.*, 1986; Thorstad and Gabrielse, 1986) or part of the stratigraphic succession that overlies the Kutcho assemblage (Panteleyev and Pearson, 1977b; Childe and Thompson, 1997). Here, it is included in the succession that overlies the Kutcho assemblage, possibly across a significant disconformity. This interpretation is based on the abrupt lower contact of the conglomerate unit, a provenance that is dominated by a variety of lithologic units within the underlying Kutcho assemblage, and a gradational contact with the overlying Sinwa Formation. The conglomerate may have a limited lateral extent, because it is not present in the syncline south of its exposure belt, where the Sinwa Formation rests directly above the central division of the Kutcho assemblage.

The conglomerate unit generally weathers to a light greenish grey to brownish grey colour, and consists of flattened pebbles and cobbles within a schistose matrix of chlorite, sericite and sand-size grains of quartz and feldspar (Figure 17). The clast population is dominated by a variety of pale grey felsic rock types, including aphanitic felsite, quartz±plagioclase-phyric felsite, quartz-sericite schist and fine to coarse grained equigranular tonalite. Less common clast types include sericite-chlorite schist, medium to dark green chlorite schist, feldspathic chlorite schist and limestone. Foliation within the schistose clasts is parallel to, and continuous with, the matrix schistosity. The conglomerate is typically unstratified, poorly size-sorted and matrix supported. Some sections, however, consist of moderately sorted pebble conglomerate that occurs in poorly defined thick beds. Locally the conglomerate is intercalated with thin to medium beds of finer grained rocks, including schistose sandstone, pebbly sandstone and grey phyllite. Lenses of limestone, up to 1.5 m wide and several tens of metres long, also occur, and some of these enclose smaller lenses of schistose granule conglomerate that contains quartz, feldspar and small felsic lithic fragments. In a fairly well-exposed section northeast of the Kutcho Creek VMS deposit, limestone lenses become gradually more abundant in the upper part of the conglomerate unit, where associated pebble conglomerate units commonly have a limestone matrix.

The conglomerate unit is not dated, but is suspected to be Late Triassic on the basis of its gradational contact with limestone correlated with the latest Triassic Sinwa Formation. It is on the order of 150 m thick along most of its exposure belt, but appears to thicken where it is folded through an anticline-syncline pair west of the Kutcho Creek VMS deposit, although the effects of internal folding on this apparent thickness are unknown. However, assuming that some of this apparent thickening is primary, it suggests that the conglomerate unit thickens to the south or southwest, toward the contact with the central Kutcho division. In contrast to this apparent southward thickening, the conglomerate unit is not even present 2 to 3 km farther south, where the Sinwa Formation rests directly above metarhyolite of the central division. This pattern suggests that the basin in which the conglomerate

Figure 17. Conglomerate of the conglomerate unit, Conglomerate ridge.

was deposited may have been controlled by a down-to-the-north growth fault located near the present contact between central and northern divisions of the Kutcho assemblage.

Sinwa Formation

The Sinwa Formation is a limestone unit that has been traced across most of the width of north-central part of the map area, where it occupies a stratigraphic position between the underlying conglomerate unit and the overlying Inklin Formation. The Sinwa Formation is also exposed farther south, in the west-central part of the map area, where it outlines a faulted syncline cored by the Inklin Formation. The conglomerate unit is not present in this area, and the Sinwa limestone rests directly above metarhyolite of the central division of the Kutcho assemblage. The width of the Sinwa Formation in map-view suggests that it has a stratigraphic thickness ranging from a few tens of metres to almost 100 m in the north-central part of the map area, although the apparent thickness may be modified by internal folding, as it appears be in the large area of limestone exposures on the north limb of the syncline in the west-central part of the map area.

The Sinwa Formation consists almost entirely of grey and white, weakly to moderately foliated, recrystallized limestone that weathers to a uniform light grey to medium brownish grey colour (Figure 18). Intervals of dark grey, fine-grained limestone and slaty limestone occur locally. The basal contact with underlying conglomerate in the northern belt appears to be gradational, as suggested by the common occurrence of limestone lenses in the upper part of the conglomerate unit, and local intercalations of calcareous, schistose conglomerate, compositionally similar to the underlying unit, within the basal part of the Sinwa. The contact between Sinwa limestone and underlying Kutcho metarhyolite in the west-central part of the map area was not observed, but it is well constrained locally, and appears to be sharp and probably disconformable.

The type area of the Sinwa Formation is at Sinwa Mountain in the Tulsequah map area (NTS 104K), almost 300 km west-northwest of Kutcho Creek (Souther, 1971). There, the formation comprises late Upper Triassic (Norian) limestone that occurs in the hangingwall of the King Salmon thrust fault, and is stratigraphically overlain by the Lower Jurassic Inklin Formation. Exposures of Sinwa Formation are intermittent between the type area and the current map area (Gabrielse, 1998), but the correlation is reasonable, given the commonality of stratigraphic position directly beneath the Inklin Formation and structural setting within the King Salmon allochthon. The Sinwa Formation is not dated in the current map area, but fossils collected from correlative limestone west of Kutcho Creek include schleractinian corals, consistent with a Late Triassic age (Panteleyev and Pearson, 1977b; Monger, 1977). Samples collected from the map area in 2010 are currently being processed for conodonts.

Figure 18. Limestone, Sinwa Formation, 2 km north of peak 1732.

Inklin Formation

Clastic metasedimentary rocks assigned to the Lower to Middle Jurassic Inklin Formation form a wide belt that crosses the northern part of the map area. They are in stratigraphic contact with the underlying Sinwa Formation to the south, and are juxtaposed against ultramafic rocks of the Cache Creek terrane across the Nahlin fault to the north. The Inklin Formation is not well exposed in much of this belt, but good exposures occur on ridges south of the Nahlin fault, and along parts of Andrea Creek. The formation is also represented by a narrow belt of scattered exposures in the west-central part of the map area, where it occurs above the Sinwa Formation in the core of a faulted syncline.

The Inklin Formation consists mainly of dark to medium grey slate that typically contains small porphyroblasts of rusty Fe-Mg carbonate. Bedding is commonly defined by laminations and thin interbeds of siltstone and slaty siltstone (Figure 19). Sandstone, containing detrital quartz and feldspar, is less common, but dominates some parts of the formation. It typically occurs as thin to thick, locally graded beds intercalated

Figure 19. Laminated slate and siltstone, Inklin Formation, Andrea Creek.

with thinner interbeds of slaty siltstone. Limestone and brown weathered calcareous sandstone form thin to medium beds and lenses in the basal part of the formation, giving the impression of a gradational contact with the underlying Sinwa Formation.

The Inklin exposures within the current map area have been traced westward through the Cry Lake and Dease Lake map areas (Gabrielse, 1998) into the type area of the Inklin Formation in the Tulsequah map area (Souther, 1971). The formation is not well dated anywhere along this belt (Gabrielse, 1998), but fossil data from contiguous strata still farther to the northwest, in the Atlin Lake and Tagish Lake areas, indicate an Early Jurassic, Sinemurian to Toarcian age (Johannson *et al.*, 1997; Mihalynuk, 1999). Correlative strata farther north, in the Yukon, range from Lower to Middle Jurassic (Bajocian) (Pálfy and Hart, 1995).

Ultramafic rocks of Cache Creek terrane north of the Nahlin fault

Ultramafic rocks of the Cache Creek terrane crop out along the north margin of the study area. They are juxtaposed against the Inklin Formation across the Nahlin fault, and are truncated to the east by the Kutcho fault. They are part of a widespread ophiolitic assemblage that forms a major part of the Cache Creek terrane of northern British Columbia (Monger, 1975; Terry, 1977; Ash, 2001; English *et al.*, 2010).

The ultramafic rocks for the first 100 to 200 m north of the Nahlin fault comprise irregularly foliated and fractured serpentinite that weathers to shades of light to dark green and grey. The serpentinization is less pervasive farther north, where the protolith is largely harzburgite with local patches of dunite. The harzburgite weathers to a rusty brown colour, with an irregular surface that is the result of resistant grains of orthopyroxene, 4 to 12 mm in size, standing in relief against a recessive background inferred to be mainly serpentinized olivine. Dunite, consisting mainly of serpentinized olivine, is characterized by weathered surfaces that are relatively smooth and a lighter reddish tan colour. Lenses of chlorite schist occur locally within serpentinized ultramafite and might be tectonic inclusions or altered mafic dikes. A lens of dark grey slaty siltstone that was traced for about 150 m in a west-northwest direction, 600 m north of the trace of the Nahlin fault, is probably a fault-bound sliver derived from the Inklin Formation.

Ultramafic rocks along the Kutcho fault are altered to orange weathered listwanite which forms a conspicuous band up to 200 m wide. Listwanite was also noted along a minor north-striking fault within the main part of the ultramafic unit, several kilometres west of the Kutcho fault. The listwanite consists of finely crystalline magnesite, locally with scattered small grains of mariposite, cut by variably oriented veins of quartz and magnesite.

Plutonic rocks of Quesnel terrane

Granitic rocks that crop out on the northeast side of the Kutcho fault are part of an unnamed and undated pluton within Quesnel terrane. The pluton cuts Late Triassic volcanic and sedimentary rocks of the Shonektaw Formation to the east and northeast of the map area (Gabrielse, 1998). Exposures examined in the northern and central parts of the current study area comprise a heterogeneous mixture of hornblende diorite to quartz diorite and hornblende-biotite tonalite, with numerous patches of dark grey hornfels and fine grained dioritic rock that probably represent screens of country rock and/or older phases of the pluton. Exposures in the southern part of the area are more homogeneous, consisting of grey-green, medium grained, equigranular hornblende granodiorite.

Bowser Lake Group

Rocks assigned to the Bowser Lake Group form the southernmost unit mapped within the study area, where they occur in the footwall of the King Salmon thrust fault. They were examined in several exposures along lower Josh Creek near the eastern edge of the map area, and in a small exposure in the southwestern part of the area, on the wooded slopes near the southern limit of mapping. Pebble conglomerate forms the latter exposure, and is the dominant lithology in the Josh Creek exposures. It weathers brown to rusty brown, and contains subangular to subrounded clasts ranging from a few millimetres to 5 cm in size. The clasts are dominated by chert, in shades of light to dark grey and light to medium green, but fragments of mafic volcanic rock, siliceous argillite and quartz are also present. The small size fraction grades into a sandy matrix dominated by grains of chert and quartz.

Brown weathered, fine to coarse-grained sandstone, composed mainly of chert and quartz, occurs as single or multiple thin to medium beds intercalated with conglomerate in the Josh Creek exposures. Some beds are graded, and overlying conglomerate forms a channel cutting into the top of one sandstone bed.

The Bowser Lake Group along Josh Creek also includes exposures of dark grey slate that were not seen in stratigraphic contact with the dominant conglomerate. The slate is highly folded and faulted, and contains cleavage-parallel veins and lenses of rusty weathered Fe-Mg carbonate.

The Bowser Lake Group ranges from Middle Jurassic to Early Cretaceous in age (Tipper and Richards, 1976; Evenchick, 1991). The panel of rocks in the current map area probably represents part of the lower, Middle Jurassic, portion of the group (Gabrielse, 1998); it has yielded Bajocian fossils 30 km west of the map area, and is cut by a late Middle Jurassic pluton 15 km southeast of the map area.

Eocene intrusions

Small, intermediate to mafic, post-metamorphic intrusions are scattered sparsely through much of the map area, and are common within the Kutcho assemblage and Cache Creek Complex in the southwestern part of the area. Most of the intrusions are porphyritic sills and dikes, ranging from a few metres to a few tens of metres wide, comprising phenocrysts of feldspar, hornblende and locally pyroxene, within a grey to brown, massive to platy, aphanitic to very fine grained feldspathic groundmass. Medium grained, equigranular diorite that might be part of the same plutonic suite forms a small stock, 300 m in diameter, that underlies peak 2075, and also a north-northeast striking dike, 6 to 8 m wide, that cuts schists of unit KN3 about 1 km northeast of peak 1732. The diorite contains approximately equal proportions of plagioclase and mafic minerals, the latter comprising clinopyroxene, hornblende and biotite.

The intrusive suite described above is inferred to be Eocene, on the basis of a radiometric date obtained from a dike that crops out 1 km northeast of peak 2075. Stevens *et al.* (1982) report that a hornblende separate, containing about 10% biotite, from this dike yielded a K/Ar date of 55.4 ±3.0 Ma.

STRUCTURE

Mesoscopic structure

All map units within the King Salmon allochthon are characterized by a penetrative cleavage or schistosity defined by the preferred orientation of greenschist facies metamorphic mineral assemblages and, in coarse-grained units, variably flattened primary crystal and lithic fragments. The schistosity typically dips at moderate to steep angles to the north, and is axial planar to mesoscopic folds of bedding which were observed sporadically within well-bedded units. The folds plunge gently to the west or west-northwest, and typically verge to the south. Lineations defined by bedding/cleavage intersections and, rarely, the elongation of mineral and lithic fragments, are parallel to the fold axes. A younger crenulation cleavage, which dips more gently to the north, was observed to cut the schistosity at a few locations scattered across the map area. It is best developed in the Inklin Formation within the core of the syncline 2.5 km north-northeast of peak 2075. There, the crenulation cleavage dips 30 to 40 degrees to the north, and is axial planar to open folds of the main slaty cleavage that plunge gently to the west-northwest. The main schistosity is also deformed by another, more common set of mesoscopic folds and kinks with axes that plunge steeply to the north or northeast. Axial surfaces are typically steep and do not have an associated cleavage.

Macroscopic structure of the King Salmon allochthon

The macroscopic structure of the King Salmon allochthon comprises predominantly north dipping and facing map units that are locally deformed by south-verging asymmetric folds and(?) north dipping thrust faults (Figure 3). The folds formed at the same time as the penetrative schistosity displayed by all units within the allochthon. The bounding King Salmon and Nahlin thrust faults, as well as the inferred north dipping thrust faults within the allochthon, probably formed during the same deformational event, but in detail may be slightly younger. A variety of constraints beyond the current map area suggest that this deformation occurred in early Middle Jurassic time (Tipper, 1978; Mihalynuk *et al.*, 1992, 2004).

The Cache Creek rocks that form the base of the allochthon in the southwest part of the map area are inferred to underlie the Kutcho assemblage across a north dipping thrust fault that appears to merge with the King Salmon fault. The overlying southern division of the Kutcho assemblage forms a panel that mainly dips and faces to the north. The sinuous contact between units KS1 and KS2 is suspected to be the result of stratigraphic interfingering, but might indicate the presence of an east-plunging south-verging fold pair.

The central division of the Kutcho assemblage structurally overlies the southern division with no apparent discordance. The contact is interpreted to be stratigraphic, but is not well enough exposed to preclude the presence of significant layer-parallel faults. A west-plunging syncline in the southwestern part of the division is defined by infolded Sinwa and Inklin formations, and a poorly defined complimentary anticline to the north is apparently cored by metarhyolite and tonalite. The northern part of the central division occupies the north limb of this anticline, and is deformed by numerous mesoscopic and medium-scale folds that show southward vergence, as defined by long moderately north-dipping backlimbs and short, steeply-dipping forelimbs.

The northern part of the King Salmon allochthon, including the northern division of the Kutcho assemblage and overlying sedimentary units, forms a predominantly north dipping and facing succession that is deformed by a west-plunging, south-verging anticline/syncline pair that is well defined by the conglomerate unit and overlying Sinwa Formation. The Inklin Formation displays considerable internal folding and might encompass additional folds of similar magnitude, but was not examined in sufficient detail to determine if this is the case. The structure of the southern part of this panel, including the contact between the northern and central divisions of the Kutcho assemblage, is not well understood. It is suspected that the boundary between the two divisions is a system of faults, in part because there is an apparent truncation of medium-scale folds in the central division along this contact in the western part of the map area. Farther east, there is a structural(?) interleaving of central and northern division lithologies across recessive contacts that are suspected, but not proven, to be faults. This system of inferred faults may have accommodated south-directed thrust movement, congruent with other major structures within and bounding the King Salmon allochthon. However, as discussed previously, these faults may, in part, have originated at an earlier time, as down-to-the-north growth faults that localised deposition of the conglomerate unit.

The youngest structures mapped within the King Salmon allochthon are steeply dipping, northwest-striking faults that correspond to local offsets of the predominantly east trending lithologic contacts and structures. These late structures display both dextral and sinistral apparent offsets, but the actual sense of movement was not established.

King Salmon thrust fault

The King Salmon fault is an important regional structure that forms the structural base of the King Salmon allochthon. It has been traced about 300 km west-northwest from the current map area, where it apparently merges with the long-lived, northwest trending Llewellyn fault zone (Mihalynuk, 1999). Where exposed, the King Salmon fault dips at low to moderate angles to the north, and displays deformation fabrics and map relationships consistent with south-directed thrust motion (Souther, 1971; Thorstad and Gabrielse, 1986; Gabrielse, 1998).

The King Salmon thrust fault crosses the southern part of the map area, but its position is well constrained only in the southwest corner of the area, southwest of peak 1667, and along the lower reaches of Josh Creek in the southeast part of the area. In the southwest, the fault separates the Cache Creek Complex from the Bowser Lake Group. It is constrained by exposures of Cache Creek serpentinite and Bowser Lake chert-pebble conglomerate about 200 m apart, but no structures or fabrics related to the fault were observed.

The fault is more tightly constrained along Josh Creek, where it is defined by exposures of Kutcho assemblage and Bowser Lake Group about 30 m apart. The Kutcho rocks directly above the fault are part of unit KS1, and consist mainly of dark grey phyllite that locally contains thin to medium graded sandstone beds that dip and face 45º to the north-northwest. The grey phyllite is commonly altered to pale green, rusty weathered ankerite-sericite schist, and the phyllitic cleavage is contorted by folds with highly variable orientations. Folds within altered ankerite-sericite schist near the structural base of the exposure, however, generally plunge gently to the east or west, and, where asymmetric, verge to the south. Exposures of footwall Bowser Lake Group most proximal to the fault trace consist of chert pebble conglomerate with local graded sandstone interbeds that are vertical and face to the north-northeast. These rocks are cut by brittle faults that dip at moderate to steep angles to the north, and locally display downdip striations. Farther to the southeast, an isolated exposure displays a minor thrust(?) fault that dips 45º to the north and places massive chert-pebble conglomerate above contorted magnesite-altered slate that is also part of the Bowser Lake Group. Similar magnesite-altered slate forms a larger exposure farther downstream, but still within 100 m of the King Salmon fault trace. In this exposure the slaty cleavage is folded by northeast-plunging folds that are cut by younger faults that dip at moderate to steep angles to the east-northeast.

Nahlin fault

The Nahlin fault has been traced from the current map area more than 350 km west-northwest to the Atlin Lake area (Souther, 1971; Mihalynuk *et al.*, 1992; Gabrielse, 1998). It forms the northeast boundary of the King Salmon allochthon, and juxtaposes the Inklin Formation, on the southwest side of the fault, with rocks of the Cache Creek terrane to the northeast. The fault is generally interpreted as a northeast-dipping thrust, although some segments dip steeply and may have a component of dextral strike-slip movement (Gabrielse, 1998).

The trace of the Nahlin fault trends east-southeast across the northern part of the map area, and bends sharply to the southeast as it is truncated by the Kutcho fault. It juxtaposes ultramafic rocks of the Cache Creek terrane to the north and northeast against the Inklin Formation to the south and southwest. The fault is easily identified where it crosses alpine ridges and juxtaposes green serpentinite against grey metasedimentary rocks, but it was not studied in enough detail to establish its orientation or kinematic history. A notable feature, however, is the common presence of lenses of rock along the fault trace that are not derived from either the Cache Creek ultramafic unit or the Inklin Formation. These lenses include limestone, sericite-quartz schist (metarhyolite?), silicified chlorite-sericite schist and actinolite-epidote-chlorite schist. They resemble rocks that are common in the Sinwa Formation and the Kutcho assemblage, and may have been derived from these units as the fault ramped through them into the overlying Inklin Formation.

Kutcho fault

The Kutcho fault is a prominent northwest striking regional structure that truncates the east end of the King Salmon allochthon. It is part of a network of orogen-parallel dextral strike-slip faults, of Cretaceous to Eocene age, with a combined displacement of several hundred kilometres (Gabrielse, 1985; Gabrielse *et al.*, 2006). The Kutcho fault displays mylonitic fabrics with dextral kinematic indicators where it cuts the Cassiar Batholith to the northwest of the current map area (Gabrielse, 1998). Right-lateral displacement of about 100 km is indicated by offset of the Hottah and Klinkit faults, which are truncated by the Kutcho fault 15 and 115 km northwest of the present map area (Gabrielse, 1985). Restoration of an additional 200 km of displacement, distributed along other faults of the network (Thibert, Thudaka, Finlay, Ingenika, Takla), matches the King Salmon allochthon with correlative units included in the Sitlika assemblage of central British Columbia (Monger *et al.*, 1978; Gabrielse, 1985).

The Kutcho fault transects the northeast corner of the Kutcho-Tucho map area, where it truncates the Kutcho assemblage and overlying units, and juxtaposes them against granitic rocks of Quesnel terrane. The fault is easily defined by the contrasting rock packages it separates, and its trace is highly visible through much of the area because ultramafic rocks directly southeast of the fault are altered to orange weathered listwanite. Granitic rocks directly northeast of the fault are highly fractured and altered with chlorite, epidote and carbonate. The deflection of the Nahlin fault into the younger structure is consistent with dextral movement along the Kutcho fault.

MINERAL OCCURRENCES

The Kutcho Creek Cu-Zn volcanogenic massive sulphide deposit occurs within the upper part of the Kutcho assemblage about 6 km east of Kutcho Creek. Known mineralization elsewhere within the map area is restricted to a few minor occurrences of disseminated chalcopyrite and sphalerite. Some of these, however, are associated with extensive zones of pyrite-sericite-quartz alteration, indicating that there is potential for future discoveries within the Kutcho assemblage.

Kutcho Creek (MINFILE 104I 060)

The Kutcho Creek volcanogenic massive sulphide deposit is hosted by the northern division of the Kutcho assemblage on the south side of Andrea Creek. The deposit comprises three lenses of massive sulphide that form a linear, west-northwest trending belt about 3.5 km long. These lenses were originally named, from east to west, the Kutcho, Sumac West and Esso West deposits (Bridge *et al.*, 1986), but are currently referred to as the Main, Sumac and Esso deposits (Makarenko *et al.*, 2010). The deposit was not examined during the current study, and the summary presented here is based mainly on the published reports of Bridge *et al.* (1986) and Barrett *et al.* (1996), as well as a preliminary economic assessment prepared for Kutcho Copper Corporation by JDS Energy and Mining Inc. in July 2010 (Makarenko *et al.*, 2010).

The Kutcho Creek deposit was detected in 1967 by anomalous values for Cu and Zn in a stream sediment sample collected during a joint-venture regional geochemical survey operated by Imperial Oil Ltd. Subsequent prospecting in 1968 identified pyritic quartz-sericite schists, and claims were staked over the not-yet-discovered Main lens. These claims were allowed to lapse, but Imperial Oil Ltd. returned to restake the area in 1972. However, Sumac Mines Ltd. had staked claims in the same area earlier that year, after locating disseminated pyrite-chalcopyrite mineralization during follow-up exploration of a Cu-Zn stream sediment anomaly in a creek west of the Imperial Oil anomaly. The staking by Imperial Oil (later to become Esso Minerals Canada Ltd.) in 1972, and additional staking in the following years, generated a large claim block that surrounded the Sumac claims. Subsequent exploration by both companies, including about 60 000 m of diamond drilling carried out between 1974 and 1982, outlined the 3 massive sulphide lenses, with the western part of the Main lens and the Sumac lens located within the claim block held by Sumac Mines Ltd., and the eastern part of the Main lens and the Esso lens located on claims held by Esso Minerals Canada Ltd. A partnership agreement to conduct engineering and development work was signed by the two companies in 1983, and a prefeasibility study was completed in 1985, but the project was then put on hold pending further exploration results.

Homestake Canada Ltd. bought most of Esso's mining assets in 1989. Some regional and deposit-scale work was carried out on the Kutcho property in 1990 and 1992 under option agreements with American Reserve Mining Corp. and Teck Cominco Ltd. Homestake was purchased by Barrick Gold Corp. in 2003, and Western Keltic Mines Inc. purchased the Kutcho property from Barrick and Sumitomo in 2004. Western Keltic carried out drill programs on the Kutcho deposit in 2004, 2005 and 2006, and completed a pre-feasibility study in 2007. In May 2008 Sherwood Copper Corp. acquired Western Keltic Mines Ltd., and amalgamated it with a wholly owned subsidiary to create the Kutcho Copper Corporation. Later that same year, Sherwood merged with Capstone Mining Corp., such that Kutcho Copper Corporation, owner of the Kutcho property, became a wholly owned subsidiary of Capstone Mining Corp. Major drilling programs were carried out by Kutcho Copper Corporation in 2008 and 2010. The company released a preliminary economic assessment in September 2009, and a revised preliminary economic assessment in July 2010.

The three massive sulphide lenses that comprise the Kutcho Creek deposit occur at about the same stratigraphic level, at the top of unit KN2, and define a west-northwest plunging linear array, 3.5 km long, that probably defines the intersection of a fracture or fault system with the seafloor at the time of their accumulation. The individual lenses are elongate parallel to this trend, and approximately conformable with the enclosing stratigraphy. The east end of the Main lens intersects the topographic surface, and the Esso lens occurs at depths of 400-500 m below the surface. Drillholes have intersected several additional small massive sulphide pods up to 450 m west of the Esso lens, along the same linear trend. The Main lens is the largest and best defined, and measures about 1500 m long by 260 m wide, with a maximum thickness of 36 m. The Esso lens is smaller but higher grade, and was the main target of the 2010 diamond-drill program by Kutcho Copper Corporation. The intervening Sumac lens is fairly large but remains poorly defined because of relatively low grades. In detail, individual lenses comprise multiple layers of massive to disseminated sulphide, dominated by pyrite, sphalerite, chalcopyrite and bornite, interspersed with carbonate-quartz-sericite schist and massive to laminated dolomite. The sulphide lenses are underlain by pyritic quartz-sericite-carbonate schists with foliation parallel quartz-pyrite veins that may represent tectonically transposed stockwork veins. Sulphide content decreases sharply across the upper contacts of the massive sulphide lenses, but chemical alteration effects that extend at least 100 m into the footwall, mainly Na depletion and variable additions of Mg, Ca, Si and Fe, also continue for 10 to 20 m into the hangingwall.

Capstone Mining Corp. (now Kutcho Copper Corporation) announced results of an independent NI43-101 compliant mineral resource estimate for the Kutcho Creek deposits in February 2009 (Capstone Mining Corp., 2009). The estimate was completed by Garth Kirkham, P.Geo., of Kirkham Geosystems Ltd., and was based on all drillholes completed prior to that time, including those from a 2008 program designed to better define the mineralization within the Main deposit. Using a 1.5% Cu cut-off, the Main deposit has a measured resource of 5 421 296 t grading 2.15% Cu, 2.86% Zn, 31.45 g/t Ag and 0.34 g/t Au; an indicated resource of 4 042 659 t grading 2.04% Cu, 2.54% Zn 31.15 g/t Ag and 0.35 g/t Au; and an inferred resource of 464 457 t grading 1.84% Cu, 2.83% Zn, 31.55 g/t Ag and 0.43 g/t Au. The Sumac deposit has an inferred resource of 625 577 t grading 1.67% Cu, 1.46% Zn, 30.12 g/t Ag and 0.29 g/t Au. The 2009 resource estimate for the Esso deposit has recently been updated, following a 2010 infill drill program that demonstrated continuity of high grade mineralization over significant distances. Using a 1.5% Cu cut-off, the Esso deposit now has an indicated resource of 1 816 200 t grading 2.69% Cu, 6.18% Zn, 64.8 g/t Ag and 0.66 g/t Au (Capstone Mining Corp., 2010).

Eastern extension of the Kutcho horizon

The Kutcho Creek massive sulphide deposits occur at the top of unit KN2. This unit has been traced more than 5 km eastward from the Kutcho Creek deposits, to the area north and northeast of peak 1732. It is not well exposed, but is characterized by fissile quartz-sericite schists that commonly contain substantial amounts of disseminated pyrite. Drill tests that have been conducted at several localities along this trend confirm that the unit hosts substantial intervals of pyrite-sericite-quartz alteration, locally with anomalous copper and zinc concentrations (Bridge, 1978; Holbek, 1990; Weiss *et al.*, 2006). One of these drillholes, 1100 m north of peak 1732, intersected a thin massive sulphide (mainly pyrite) zone that yielded 0.03% Cu, 0.02% Zn, 0.03% Pb, 6.17 ppm Ag and 0.07 ppm Au over 0.5 m (Bridge, 1978, hole 78).

Jenn

The Jenn occurrence is hosted by schists in the upper part of the central Kutcho division, about 700 m east of peak 1732. It comprises scattered narrow intervals of disseminated to semimassive pyrite, locally with traces of chalcopyrite and sphalerite, which were intersected in drillholes bored by Esso Minerals Canada between 1974 and 1983 (Oddy and Neilans, 1974, 1975; Bridge, 1983). The sulphide intervals are hosted mainly by quartz-sericite schists derived from felsic volcaniclastic rocks, but the host succession also includes, metarhyolite, chlorite schist, siltstone and phyllite.

CK (MINFILE 104I 075) and Kris occurrences

The CK occurrence is hosted by a broad zone of pyritic sericite-quartz altered rocks within the lower part of the central Kutcho division along Josh Creek (Figure 20). Belik (1978) notes that traces of chalcopyrite and sphalerite occur in tabular to lenticular zones of heavily disseminated pyrite hosted by quartz-sericite schist that contains relict quartz eyes. The altered rocks were tested with several diamond-drill holes in 1990, which intersected narrow zones of semimassive to massive pyrite that are enriched in copper and zinc (Holbek, 1990).

Pyritic quartz-sericite schists are common within the lower part of the central Kutcho division within a belt that extends at least 7 km west from the CK occurrence, to the slopes east of Kutcho Creek. The pyritic zones occur mainly in altered felsic volcanic and volcaniclastic rocks, but some comprise narrow zones of pyritic cherty rock that are interpreted as exhalites, and these occur within both felsic and mafic schists of the central division, and also in mafic schists of unit KS2 of the underlying southern division (Holbek, 1990; Alldrick *et al.*, 2009b). The Kris occurrence, in the northern part of this belt, comprises minor amounts of chalcopyrite that occur in several different pyritic zones, within felsic volcaniclastic rocks, that were intersected in a diamond-drill hole cored by Homestake in 1990 (Holbek, 1990; Alldrick *et al.*, 2009a).

Kass (MINFILE 104I 095)

The Kass showing occurs in the southwest part of the

Figure 20. Pyrite-sericite-quartz schist, CK occurrence, Josh Creek.

map area, within schists of unit KS1 just north of the small diorite plug that forms peak 2075. The schists enclose several lenses of pyrrhotite, with minor amounts of chalcopyrite and sphalerite, which were discovered in 1982, and further evaluated in 1983, during exploration programs by Canamax Resources Inc. (Fleming and Roth, 1983). The pyrrhotite lenses range from 0.5 to 1 m in width, and vary from laminated to brecciated. Grab samples returned up to 1100 ppm Cu, 1700 ppm Zn and 6.17 ppm Ag (Fleming and Roth, 1983). The mineralized lenses have been documented in only a very small area, and have apparently received little attention since their initial discovery.

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