Bedrock geology of the Duke River area, parts of NTS 115G/2, 3, 4, 6 and 7, southwestern Yukon

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ABSTRACT

The Duke River area comprises Late Paleozoic arc volcanic and sedimentary rocks, Triassic basalts, carbonate and sedimentary rocks, overlain by Tertiary terrestrial sedimentary and volcanic deposits. These rocks are intruded by Upper Triassic to Miocene plutons, sills and dykes. Post-late Paleozoic uplift and erosion are suggested by the lack of Early Triassic rocks, as well as a higher degree of folding exhibited by the older stratigraphy. A subsequent, compressional episode thrust Paleozoic rocks over Triassic rocks and folded the strata into upright, to overturned, tight folds. This event is younger than the Upper Triassic to Cretaceous Tatamagouche succession, but older than mid-Cretaceous plutons. Post-Cretaceous, steeply dipping strike-slip faults dissect the area and include both extensional and compressional components. A recent compressional event is exhibited by Triassic rocks thrust over folded Tertiary strata. The structural complexity of the area is significant, as it affects exploration targeted at mineralized Upper Triassic ultramafic intrusions.

RÉSUMÉ

Dans la région de la rivière Duke reposent des roches sédimentaires et d'arc volcanique du Paléozoïque tardif ainsi que des basaltes, des roches sédimentaires et des roches carbonatées du Trias recouverts par des dépôts sédimentaires et volcaniques d'origine terrestre du Tertiaire. Ces roches sont pénétrées par des plutons, des filons-couches et des dykes datant du Trias supérieur au Miocène. L'absence de roches du Trias précoce ainsi que le plissement plus intense des strates plus anciennes suggèrent qu'il y a eu soulèvement et érosion après le Paléozoïque tardif. Un ultérieur épisode de compression a poussé les roches du Paléozoïque sur les roches du Trias et plissé les strates en plis serrés droits à déversés. Cet épisode est plus récent que la succession de Tatamagouche datant du Trias supérieur au Crétacé, mais plus ancien que les plutons du Crétacé moyen. Des failles décrochantes post-crétacé fortement inclinées dissèquent la région et présentent des composantes d'extension et de compression. Les roches du Trias poussées sur les strates plissées du Tertiaire témoignent d'un événement de compression récent. La région est d'une grande complexité structurale, ce dont doit tenir compte l'exploration ciblant les intrusions ultramafiques minéralisée du Trias supérieur.

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INTRODUCTION

The Kluane Ranges project was initiated in 2004. Bedrock mining was carried out at 1:50 000 scale in an effort to increase geologic knowledge of southwest Yukon. The project focuses on the Paleozoic and Mesozoic volcanic, sedimentary and intrusive rocks of Wrangellia Terrane, and Mesozoic to Cenozoic overlap assemblages that occur in a southeastward-tapering wedge between the St. Elias Mountains and the Denali Fault (Fig. 1). The area includes several styles of mineralization including significant deposits related to Upper Triassic mafic-ultramafic intrusions. Mapping in the Kluane Ranges emphasizes the resolution of the complex stratigraphic and structural relationships found within the area, to better constrain the overall tectonic and geologic understanding.

Mapping in 2004 centred on the Quill Creek area, between the Donjek River and the Alaska Highway and is summarized by Israel and van Zeyl (2005). Fieldwork conducted between June and August, 2005 centred on the Duke River area, extending the 2004 map area to the southeast to cover the region between Kluane National Park and Reserve and the Alaska Highway (Fig. 1; Israel *et al.*, 2005).

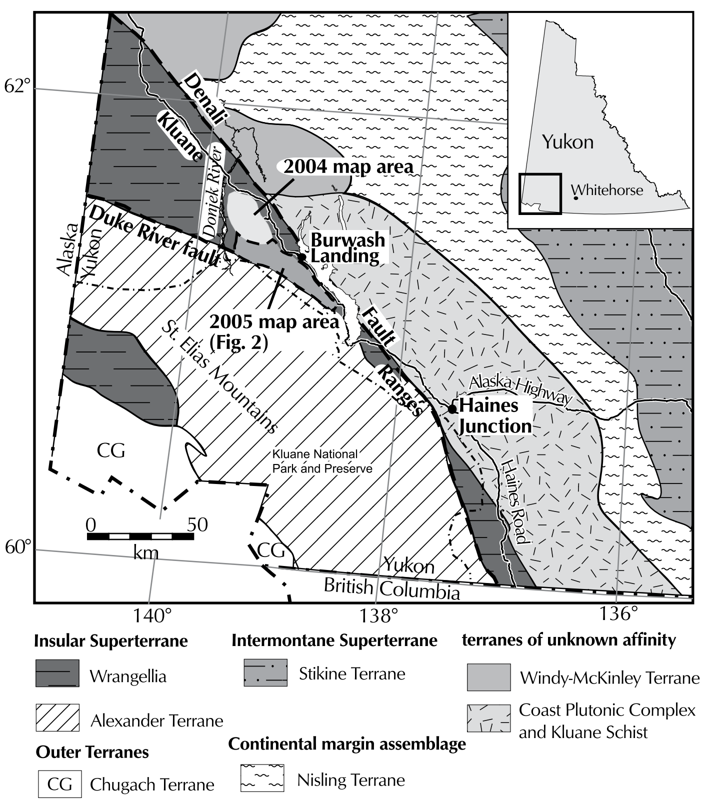

Figure 1. *Terrane map of southwest Yukon, displaying the distribution of the Wrangellia Terrane (after Wheeler et al., 1991). The location of Figure 2 is highlighted.*

The Duke River area encompasses the range of mountains between the Shakwak Valley and the Duke River. It includes the Burwash Uplands and continues southeast to Congdon Creek (Fig. 2). Geologic mapping by Muller (1967), Read and Monger (1976), Dodds and Campbell (1992) and T. Bremner (unpublished data) have aided in the preliminary interpretations presented in this report.

REGIONAL GEOLOGY

The Kluane Ranges are almost entirely underlain by the Wrangellia Terrane. Wrangellia Terrane is exposed in the Yukon in two fault-bounded tectonic blocks separated by the Alexander Terrane (Fig. 1). The Alexander Terrane at this latitude is composed of Cambrian to Devonian meta-sedimentary and meta-volcanic rocks intruded by Pennsylvanian to Early Permian plutons. A Pennsylvanian pluton cross-cuts Wrangellia and Alexander terranes in Alaska, suggesting the two terranes were together as one tectonic element by late Paleozoic time (Gardner *et al.*, 1988). Together with the Peninsular Terrane, they form the Insular Superterrane and were accreted to the western margin of the Intermontane Superterrane by at least Middle Jurassic (van der Heyden, 1992; Monger and Nokleberg, 1996; Gehrels, 2001). Jura-Cretaceous sedimentary and volcanic rocks of the Gravina-Nutzotin belt overlap Wrangellia and Alexander terranes throughout the Yukon and Alaska. Northeast of the Kluane Ranges, metamorphic and igneous rocks of the Nisling and Windy-McKinley terranes and the Kluane schist and Coast Plutonic Complex are juxtaposed next to Wrangellia Terrane across the Denali Fault (Fig. 1). The Nisling Terrane is a metamorphosed continental assemblage of late Proterozoic and lower Paleozoic schists, quartzites, marbles and meta-basites that are believed to be associated with the Yukon-Tanana Terrane (Gehrels, 2002). The Windy-McKinley Terrane is an enigmatic assemblage of Paleozoic to Mesozoic oceanic sedimentary and volcanic rocks that are apparently thrust onto rocks of the Nisling Terrane (Gordey and Makepeace, 2001).

Wrangellia Terrane, within the Yukon and adjacent Alaska, is composed of Late Paleozoic arc volcanic and sedimentary rocks of the Skolai Group, unconformably overlain by sparse outcrops of Middle Triassic marine sedimentary rocks, Upper Triassic oceanic flood basalts of the Nikolai formation, and shallow marine carbonates and mudstones of the Chitistone limestone and McCarthy Formation (Muller, 1967; MacKevett, 1971; Read and Monger, 1976; Israel and van Zeyl, 2005). The Skolai Group is divided into a Pennsylvanian (?) to Early Permian, lower volcanic unit known as the Station Creek Formation, and an upper sedimentary unit known as the Hasen Creek Formation (MacKevett, 1971; Read and Monger, 1976). The Station Creek Formation represents a Late Pennsylvanian to Permian volcanic arc that was overlain by marine sedimentary deposits of the Hasen Creek Formation during arc subsidence. Middle to Upper Triassic igneous bodies of the Kluane mafic-ultramafic complex intrude into the Skolai Group and are thought to be feeders to the overlying flood basalts of the Nikolai formation. These flood basalts are believed to be part of a large oceanic plateau that includes the Karmutsen Formation on Vancouver Island. The flood basalts are considered the hallmark of Wrangellia Terrane from southern British Columbia to central Alaska (Hulbert, 1997; Greene *et al.*, 2005).

Jura-Cretaceous sedimentary basins overlap onto Wrangellia Terrane from south-central to central Alaska, and include the Dezadeash Formation, a thick sequence of marine turbidites found within the Kluane Ranges (Eisbacher, 1976; Ridgway *et al.*, 2002). Diorite and gabbro of the mid-Cretaceous Kluane Ranges suite intrude Wrangellia Terrane as part of the Chisana magmatic arc that formed during resurgence in north-dipping subduction (Plafker and Berg, 1994). Volcanic material related to the Chisana arc is not present within the Kluane Ranges and likely reflects a more distal position for the Dezadeash Formation.

Tertiary strike-slip faulting in a transpressional environment led to the formation of the Denali and Duke River faults and subsequent formation of pull-apart and compressional basins into which the Amphitheatre Formation terrestrial sediments were deposited (Read and Monger, 1976; Dodds and Campbell, 1992; Ridgway *et al.*, 1992; Trop *et al.*, 2002). Local extension within the Kluane Ranges allowed for eruption of the Wrangell Lavas that overly much of the Amphitheatre Formation.

GEOLOGY OF THE DUKE RIVER AREA

The following briefly describes the stratigraphy of the Duke River area with emphasis on the upper Mesozoic and Tertiary strata. For a more comprehensive description of the Paleozoic and early Mesozoic stratigraphy of the area, see Israel and van Zeyl (2005).

ALEXANDER TERRANE

Only a very small component of the Alexander Terrane outcrops in the Duke River map area and it was not mapped in great detail. Included in the Alexander Terrane are meta-sedimentary rocks that outcrop in the west-central portion of the Duke River map area on the south side of the Duke River fault (Fig. 2). This unit consists of phyllites, marbles and meta-sandstones, which are all highly deformed. Intruding these rocks is the Mount Hoge pluton, a partially deformed and metamorphosed, coarse- to medium-grained hornblende biotite-granite. The Mount Hoge pluton is part of the Pennsylvanian to Permian Icefield suite that intrudes much of the Alexander Terrane in southwest Yukon (Read and Monger, 1976; Dodds and Campbell, 1988).

WRANGELLIA TERRANE

Skolai Group

The Skolai Group is the basal unit of the Wrangell Terrane in southwest Yukon and Alaska. The base of the group is either not exposed, or faulted. The Skolai Group is divided into two formations: the lower Station Creek Formation, which is dominated by volcanic rocks, and the upper Hasen Creek Formation, which is dominated by sedimentary rocks (Smith and MacKevett, 1970, MacKevett, 1971; Read and Monger, 1976; Israel and van Zeyl, 2005).

- Station Creek Formation

The Station Creek Formation outcrops extensively in the Duke River area (Fig. 2). Thickness of the unit is difficult to ascertain as the base is nowhere exposed, but it is at least several hundred metres thick. The formation is dominated by volcanic rocks that include breccias, crystal-lithic tuffs, tuffaceous siltstone and flows. Breccias are composed of sub-rounded to angular clasts, up to 50 cm in diameter in a matrix of fine-grained material of the same composition (Fig. 3). They form beds several metres thick and locally several tens of metres thick. The breccias commonly grade up into pale green to beige tuffaceous

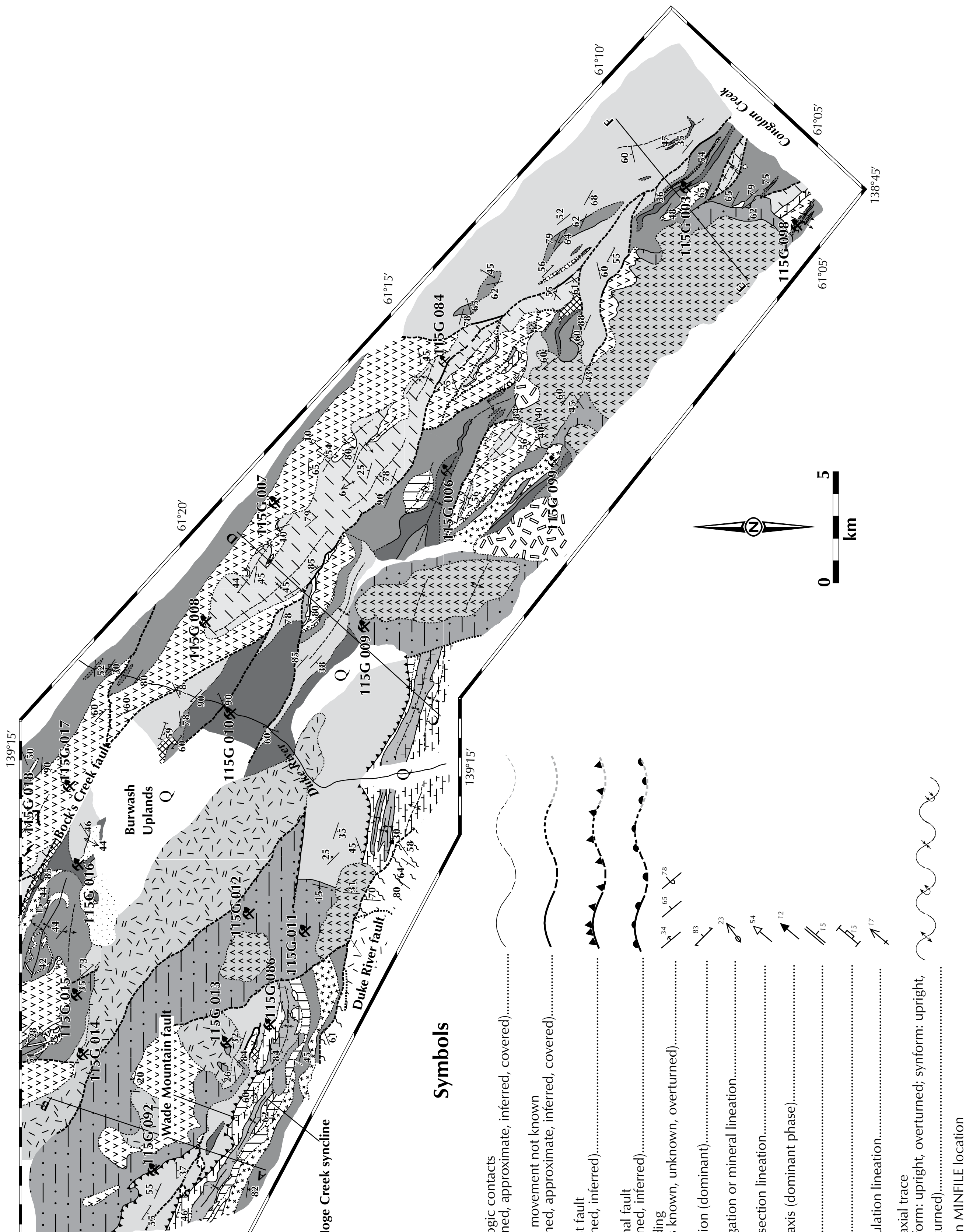

Figure 2. *Generalized geological map of the Duke River area.*

LEGEND

QUATERNARY

Q unconsolidated alluvium, colluvium and glacial deposits

INTRUSIVE ROCKS

MIOCENE

Wrangell Suite

fine- to medium-grained, hornblende ± biotite granodiorite and medium-grained biotite diorite and pyroxene gabbro

OLIGOCENE

Tkope suite

fine- to medium-grained, equigranular hornblende ± biotite quartz-feldspar porphyry

CRETACEOUS

Kluane Ranges suite

fine- to medium-grained, equigranular hornblende ± pyroxene diorite and gabbro

TRIASSIC

Maple Creek gabbro

fine- to coarse-grained diabase, and gabbro sills and dykes, locally abundant epidote and chlorite alteration; locally, columnar-jointed

Kluane mafic-ultramafic complex

coarse-grained to pegmatitic gabbro

peridotite, dunite and clinopyroxenite, layered intrusions

PENNSYLVANIAN to PERMIAN (?)

Mt. Hoge pluton

coarse- to medium-grained, hornblende-biotite granite and granodiorite

LAYERED ROCKS

PALEOGENE TO NEOGENE

Wrangell Lava

rusty red, brown, phyric and non-phyric basalt and andesite flows, interbedded with felsic tuff, volcanic sandstone and conglomerate

Amphitheatre Formation

yellow-buff to grey-buff sandstone, pebbly sandstone, polymictic conglomerate, siltstone and mudstone; minor brown-grey carbonaceous shale and coal

TRIASSIC TO CRETACEOUS

Tatamagouche succession

dark to light grey phyllite, medium- to coarse-grained sandstone, minor greywacke and pebble to cobble conglomerate; may include upper parts of McCarthy Formation

UPPER TRIASSIC

Chitistone Limestone

light grey to beige, massive to thickly bedded limestone, limestone breccia, and rare, thinly bedded limy mudstone; includes white to pale grey gypsum

McCarthy Formation

light to dark grey shale and argillite interbedded with buff-coloured limestone

Nikolai formation

thinly bedded, grey limestone and minor maroon to olive-green argillite

dark green to maroon amygdaloidal basalt and basaltic andesite flows, locally pyroxene and plagioclase-phyric; developed pillows; rare olivine crystals

light to dark green volcanic breccia; angular clasts of amygdaloidal basalt and dark grey argillite in a fine-grained matrix

MIDDLE (?) TRIASSIC

Hoge Creek succession

dark grey phyllite, locally limy, thin, grey limestone

PENNSYLVANIAN (?) AND PERMIAN

Hasen Creek Formation

light to dark grey limestone, fossiliferous and frequently pebbly, commonly graded and cross-bedded

light-grey to white bioclastic limestone, local cherty interbeds

dark to light grey-brown siltstone turbidites, siliceous argillite, chert and minor volcaniclastic sandstone and tuffs

Station Creek Formation

dark to light green volcanic breccia, crystal tuff and tuffaceous sandstone; breccia clasts consist of augite-phyric basalt within tuffaceous matrix; augite-phyric basalt flows locally amygdaloidal

UPPER PALEOZOIC/PERMIAN (?)

Alexander Terrane

grey and brown phyllite, metasandstone, unfossiliferous carbonate

Figure 2. *Legend to accompany Figure 2.*

Figure 3. *Station Creek Formation volcanic breccia located at the headwaters of Bock's Creek.*

Figure 4. *Columnar-jointed basalt flows within the Station Creek Formation located near the headwaters of Bock's Creek.*

sandstones and crystal-lithic tuffs. Sandstones are fine-grained and well bedded with individual beds ranging from less than 1 cm to 10 cm thick. Crystal tuffs are pale green with fragments of basalt (up to 1 cm) and 1-2 mm crystals of pyroxene; these tuffs are commonly interbedded with medium- to fine-grained tuffaceous sandstone. Some outcrops of these crystal tuffs are difficult to distinguish from gabbro sills and dykes that are found throughout the Skolai Group. Pale-green-weathering, pyroxene-phyric basalt flows are found throughout the Station Creek Formation. They are up to several metres thick and locally amygdaloidal; amygdules are filled with quartz, epidote and chlorite. In several localities, flows are pillowed, and in one case, exhibit columnar jointing (Fig. 4). Beds of black to dark-brown, fine-grained argillite and mudstone occur locally within the Station Creek Formation and are more prevalent at stratigraphically higher positions in the section.

The age of the Station Creek Formation is not well constrained, however, fossils found within the upper portions of the unit, as well as its gradational relationship with the Hasen Creek Formation, suggest a Pennsylvanian to Permian age (Nokleberg *et al.*, 1994).

- Hasen Creek Formation

The Hasen Creek Formation is found throughout the Duke River area, but is more extensive in the northwest portion of the map area and into the Quill Creek map area; it appears to lose much of its thickness in the southeast (Fig. 2; Israel and van Zeyl, 2005). It gradationally overlies the Station Creek Formation with the base of the formation typically placed at the cessation of volcanic material. Campbell (1981) describes the gradational contact between the two formations as a "transition zone" that records the decreasing amount of volcanic deposition and the increasing sediment input. It is at this transition zone that Hulbert (1997) suggests many of the ultramafic bodies intrude. The Hasen Creek Formation is unconformably overlain by Middle Triassic sedimentary rocks of the Hoge Creek succession and volcanic rocks of the Nikolai formation (Fig. 2).

The Hasen Creek Formation is dominated by marine clastic sedimentary rocks, carbonates, chert and conglomerates. Rare basaltic flows and volcanic breccia occur near the middle of the unit. In the Duke River area, the conglomerate, chert and carbonate units are rare and the formation is mainly composed of fossiliferous siltstone, turbidites, mudstones and fine-grained sandstones.

The age of the Hasen Creek Formation is Early Permian, based upon numerous fossil controls (MacKevett, 1971; Read and Monger, 1976; Dodds *et al.*, 1993).

Hoge Creek succession

An enigmatic package of rocks, informally named here as the Hoge Creek succession, outcrops in the westernmost, and central portions of the Duke River map area (Fig. 2). No noticeable break separates the Hoge Creek succession from the underlying Hasen Creek Formation, and only through the identification of fossils collected from the Hoge Creek succession can it be distinguished from the older sedimentary package (Muller, 1967; Read and Monger, 1976). The Hoge Creek succession is overlain by rocks of the Nikolai formation, and where the Nikolai formation is absent, the Hoge Creek succession is overlain by Chitistone Limestone and McCarthy Formation (Fig. 2). The thickness of the succession is unknown as it is restricted to slivers and discontinuous lenses.

The Hoge Creek succession consists of dark-grey argillite, beige- to brown-weathering calcareous siltstone, fine- to medium-grained sandstone, and rare beige to grey limestone. Near Hoge Creek, the succession is well bedded with alternating beds of siltstone and sandstone (Fig. 5). The age of the Hoge Creek succession is Middle Triassic (Ladinian), based upon fossils collected by Muller (1967) and Read and Monger (1976). There has been no other mention of Middle Triassic units from northern Wrangellia Terrane, however, on Vancouver Island, there is a similar package of Middle Triassic fossil-bearing strata (Carlisle and Suzuki, 1974).

Nikolai formation

The Nikolai formation is an informally named package that consists of thick accumulations of subaerial basalt flows. It outcrops throughout the Duke River map area where it unconformably overlies the Skolai Group and conformably overlies the Hoge Creek succession. It is overlain by the Chitistone Limestone, McCarthy Formation and the Tatamagouche succession (Fig. 2). Thickness of the Nikolai formation is not well constrained in the Duke River map area, but elsewhere in the Kluane Ranges, it can be up to ~1000 m thick. In the Hoge Creek area, the Nikolai formation is more or less absent, with only a thin sliver of basalt outcropping between the Hoge Creek succession and the Chitistone Limestone. The Nikolai formation consists of a sporadically formed basal breccia, a thick sequence of highly amygdaloidal basalt flows, and thin interbeds of calcareous argillite and limestone near the top of the flows. Hulbert (1997) suggests that the amount of amygdaloidal and vesicular flows within the formation demonstrate that the majority of the Nikolai formation erupted subaerially. However, rare pillows found near the base of the formation, and thin carbonate horizons near the top, indicate that at least parts of the formation erupted subaqueously (Fig. 6).

The age of the Nikolai formation is likely Late Triassic (Norian), based upon conodonts collected from the interbedded limestone. The base of the formation may be as old as Middle Triassic as it apparently conformably overlies the Hoge Creek succession.

Chitistone Limestone

The Chitistone Limestone outcrops extensively in the Duke River map area (Fig. 2). It conformably overlies the Nikolai formation, and at one locality near Bock's Creek, appears to be interbedded with the underlying basalts. Where the Nikolai formation is absent, the Chitistone Limestone unconformably overlies the Hoge Creek succession. The Chitistone Limestone is conformably overlain by the McCarthy Formation, and locally, by the Tatamagouche succession. It forms the footwall of the Wade Mountain fault, while volcanic rocks of the Station

Figure 5. *Well bedded siltstone and fine-grained sandstone of the Hoge Creek succession.*

Figure 6. *Rare pillowed flows found at the base of the Nikolai formation; outcrop located north of Hoge Creek.*

Creek Formation form the hanging wall. Thickness of the Chitistone Limestone is highly variable and can form thick packages several hundred metres thick, or thin discontinuous lenses.

The Chitistone Limestone is characterized by massive, white- to beige-weathering limestone that usually forms resistant, craggy outcrops that stand out from the surrounding rock (Fig. 7). Limestone breccia forms thick portions of the Chitistone Limestone unit and consists of blocks of white and grey limestone fragments hosted within a similar fine-grained matrix. Included within the Chitistone Limestone are deposits of white-weathering gypsum. Within the Duke River map area, gypsum outcrops north and south of Bock's Creek. A large deposit of gypsum, up to 1 km thick and 7 km in length, outcrops outside of the Duke River map area to the southeast. The Chitistone Limestone is rarely fossiliferous, but has abundant micro-fossils that yield an Late Triassic (Norian) age.

McCarthy Formation

The McCarthy Formation mainly outcrops in the western and central portion of the map area and is most obvious in the core of the Hoge Creek syncline (Fig. 2). It conformably overlies the Chitistone Limestone and grades indiscernibly into the overlying Tatamagouche succession. Thickness of the unit is impossible to determine because of the nature of folding found ubiquitously throughout the area (Fig. 8). In Alaska, MacKevett (1971) divides the McCarthy Formation into a lower member defined by shale, chert and impure limestone, and an upper member characterized by calcareous chert, spiculite, impure limestone and rare shale; together the lower and upper members have a combined thickness of over 1000 m. In the Duke River map area, both members described by MacKevett are present; however, the upper member likely includes some rocks mapped as the Tatamagouche succession since the two of these units are difficult to distinguish. The McCarthy Formation mainly outcrops as well bedded, alternating dark grey calcareous siltstone and light grey limestone. This gives the rocks a distinctive striped appearance that is easily recognizable from a distance. However, in the Hoge Creek area, rocks of the Hoge Creek succession have a similar appearance in outcrop and can easily be mistaken for the McCarthy Formation. The McCarthy Formation is locally very fossiliferous with thick death bed deposits of the bivalve *Monotis subcircularis Gabb*.

Fossils collected from the McCarthy Formation in the Duke River map area and the neighbouring Quill Creek map area are Late Triassic (Norian) in age (Israel and van Zeyl, 2005). MacKevett (1971) reports an Early Jurassic (Pliensbachian) age for fossils from the upper McCarthy Formation, suggesting an age range of Triassic to Early Jurassic for the formation.

OVERLAP ASSEMBLAGES

Tatamagouche succession

The Tatamagouche succession is a package of marine, clastic sedimentary rocks that is poorly defined within the Kluane Ranges. It has uncertain relationships with the

Figure 7. *Resistant-weathering outcrops of Chitistone Limestone; photo was taken looking east into the Duke River.*

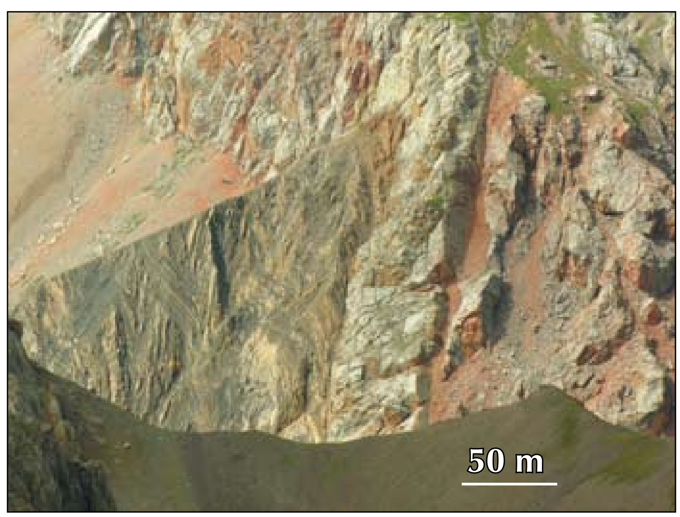

Figure 8. *Chevron folds typical of the McCarthy Formation; photo was taken looking west into the Hoge Creek syncline.*

Figure 9. *Strongly deformed conglomerate found within the Tatamagouche succession.*

Figure 10. *Poorly sorted, terrestrially deposited conglomerate of the Amphitheatre Formation.*

older strata and is unconformably overlain by Tertiary sedimentary and volcanic deposits. It likely unconformably overlies the Nikolai formation and the Chitistone Limestone and probably includes the upper portion of the McCarthy Formation in its lower sections. The Jurassic to Cretaceous portions of the succession may be, in part, equivalent to the Dezadeash Formation found to the southeast of the Duke River map area. For this reason, the Tatamagouche succession could be considered part of the Wrangellia Terrane, or as an overlap assemblage. The difficulty in separating the Tatamagouche succession from underlying rocks led Read and Monger (1976) to group together a package of rocks that ranged from Late Triassic to Early Cretaceous in age; that same division is used for this study.

The Tatamagouche succession outcrops extensively in the Duke River map area, but is more prevalent in the central and southeast portion of the study area (Fig. 2). It mainly overlies the Nikolai formation and cores large synclines, but locally overlies the Chitistone Limestone, and is in fault contact with both the Station Creek and Hasen Creek formations. The Tatamagouche succession is characterized by dark-grey argillite, fine- to medium-grained sandstone and greywacke, pebble to cobble conglomerate and calcareous siltstone. The conglomerate is composed of well rounded clasts of siltstone, limestone and granitic material, within a muddy, dark-grey matrix (Fig. 9). Locally, a brick-red conglomerate with similar clast lithologies is interbedded with greywacke and siltstone. The Tatamagouche succession is ubiquitously strongly deformed and exhibits evidence suggesting several phases of deformation. The age of the Tatamagouche succession is problematic since the unit is not well defined. Fossils range in age from Late Triassic to Early Cretaceous (Muller, 1967; MacKevett, 1971; Read and Monger, 1976; Dodds and Campbell, 1993).

Amphitheatre Formation

The Amphitheatre Formation outcrops throughout the Duke River map area with the most extensive deposit located near the Burwash Uplands in the northwest portion of the map area (Fig. 2). It typically has an unconformable lower contact with nearly all the older strata, but locally the contacts are defined by faults that were likely basin-bounding structures. Thickness of the Amphitheatre Formation ranges from 350 m to 1100 m and it is unconformably overlain by the Wrangell Lavas. It is composed of terrestrial sediments that consist of conglomerates, fine- to coarse-grained sandstones, as well as coal deposited in structurally controlled basins related to the Denali fault system (Ridgway, 1992). The conglomerates are poorly sorted with sub-rounded to well rounded clasts of quartz, dark-grey siltstone, porphyritic volcanic rocks, plutonic rocks and metamorphic rocks (Fig. 10). Discontinuous coal seams are found throughout the formation and can be up to several tens of metres in thickness. Deposition of the Amphitheatre Formation occurred in strike-slip, pull-apart basins related to movement along the Denali and Duke River fault systems (Ridgway *et al.*, 1992). Material filling the basins was derived from rocks of the Wrangellia Terrane and the Kluane Schist (Ridgway *et al.*, 1992). The age of the

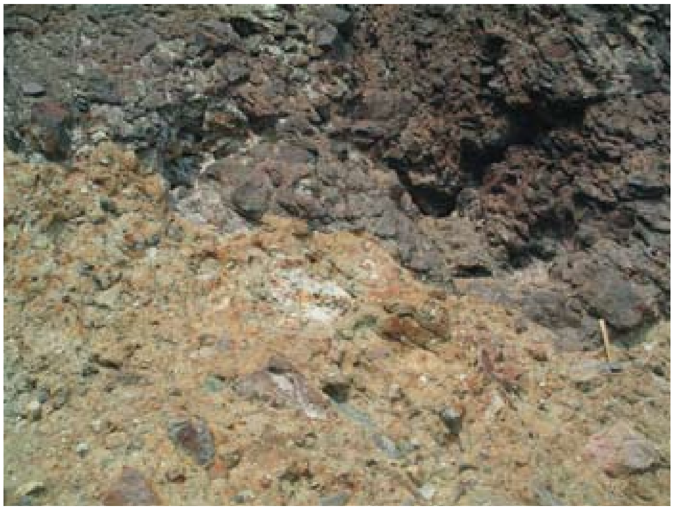

Figure 11. *Wrangell Lava basal volcanic breccia overlying the Amphitheatre Formation*

Amphitheatre Formation is Eocene to Oligocene, based on palynological studies (Ridgway *et al.*, 1992).

Wrangell Lavas

The Wrangell Lavas are the youngest rocks in the Duke River map area and outcrop extensively along the western boundary of the study area along the Duke River fault. They lie unconformably on top of the Amphitheatre Formation and, locally, have been deposited on the Skolai Group, the Nikolai formation and the Chitistone Limestone (Fig. 2). The Wrangell Lavas in the Duke River map area are a combination of volcanic rocks that include basaltic flows, andesitic flows, rare rhyolitic flows, volcanic breccias, air fall tuffs and volcaniclastic sandstones (Skulski, 1988). The upper sections of the Wrangell Lavas were not examined in this study, however, all basal contacts observed in the Duke River map area consist of flow breccia and rare pillowed flows of plagioclase-phyric basalt (Fig. 11).

INTRUSIVE ROCKS

The Duke River area is intruded by several different plutonic bodies that are variable in both composition and age (Fig. 2).

Maple Creek gabbro

The Maple Creek gabbro outcrops mainly in the northwestern portion of the Duke River map area. At this location, it occurs as sill-like bodies that intrude into the Hasen Creek Formation and along the contact between the Hasen Creek Formation and the Hoge Creek succession. It is a fine- to medium-grained, pyroxene gabbro that is believed to be coeval with the Kluane mafic-ultramafic complex and acts as a feeder to the Nikolai formation (Hulbert, 1997). It is distinguished from other gabbro sills and dykes by the less prevalent alteration and 'salt and pepper' appearance (see next section). The age of the Maple Creek gabbro is 232 ± 1 Ma defined by U-Pb analyses of zircon (Mortensen and Hulbert, 1991).

Kluane mafic-ultramfic complex

The Kluane mafic-ultramafic complex (Hulbert, 1997) comprises sills and dykes that intrude the Paleozoic stratigraphy throughout the Duke River map area (Fig. 2). Individual bodies are exposed for up to several kilometres, but thicknesses are poorly defined in the Duke River area. The largest of these intrusions, the Tatamagouche complex, is found along the Duke River, and geophysical data suggests that it underlies much of the Burwash Uplands. As the name implies, the Kluane mafic-ultramafic complex consists of both mafic and ultramafic components. Hulbert (1997) studied the complex in great detail and has described many of the bodies as being zoned with a marginal gabbro rimming phase, a peridotite/pyroxenite zone and a dunite core. The majority of ultramafic rocks examined in the Duke River area are peridotites, with varying amounts of pyroxenite. The gabbro phase associated with the ultramafic rocks tends to be coarse- to medium-grained and ubiquitously altered. This phase of gabbro is similar to sills and dykes found throughout the Duke River map area that intrude rocks of the Skolai Group. A preliminary U-Pb age of 219 Ma (J. Mortensen, pers. comm.) was obtained from one of these gabbroic bodies found along Burwash Creek. This age is significantly younger than the Maple Creek gabbro and suggests that multiple phases of Triassic gabbro exist in the study area. This may have exploration significance as mineralization associated with the Kluane mafic-ultramafic complex is commonly found within the gabbro phase; however, the age differences between the Maple Creek gabbro and other gabbros in the area raises the question of which gabbro phase should be targeted for exploration, and moreover, the actual age of ultramafic intrusions.

Kluane Ranges suite

The Kluane Ranges suite is restricted to the northern portion of the Duke River map area, where it intrudes the

Paleozoic and Mesozoic stratigraphy, and is in fault contact and is unconformably overlain by the Amphitheatre Formation (Fig. 2). It is characterized by fine- to medium-grained, hornblende ± biotite, quartz-diorite, diorite and gabbro. Copper, molybdenum and gold mineralization is associated with the Kluane Ranges suite along Burwash Creek (Fig. 2). K-Ar ages on hornblende from the main intrusive body near Burwash Creek have yielded ages of 117 Ma to 115 Ma (Christopher *et al.*, 1972) and a preliminary U-Pb zircon age of 122 Ma (J. Mortensen, pers comm.); together, these dates indicate an Early Cretaceous age for the Kluane Ranges suite.

Tkope suite

The Tkope suite outcrops exclusively along Burwash Creek, intruding the Hasen Creek and Station Creek formations, the Kluane mafic-ultramafic complex and the Kluane Ranges suite (Fig. 2). The suite is composed of white- to pale-yellow-weathering hornblende ± biotite, quartz-feldspar porphyry. Preliminary U-Pb analyses of this mafic body suggest an Oligocene age for the suite.

Wrangell suite

The Wrangell suite outcrops as two small intrusive bodies in the southeastern portion of the Duke River map area (Fig. 2). Both bodies intrude Paleozoic and Mesozoic rocks and Tertiary Amphitheatre Formation and Wrangell Lavas, making these the youngest rocks in the map area. The Wrangell suite in the Duke River map area is characterized by medium-grained, equigranular hornblende ± biotite granodiorite to diorite. The westernmost intrusion, near the Duke River, yields a U-Pb age of ~14 Ma (Dodds and Campbell, 1988).

STRUCTURE

The Duke River area is characterized by northwest-southeast structural trends resulting from several generations of deformation (Fig. 2). Three generalized phases of deformation can be separated, based upon field observations: 1) an enigmatic pre-Middle Triassic compressional event; 2) a post-Triassic, pre-mid-Cretaceous contractional event; and 3) a post-Cretaceous strike-slip faulting event. Figure 12 illustrates the general structural features observed in the Duke River map area.

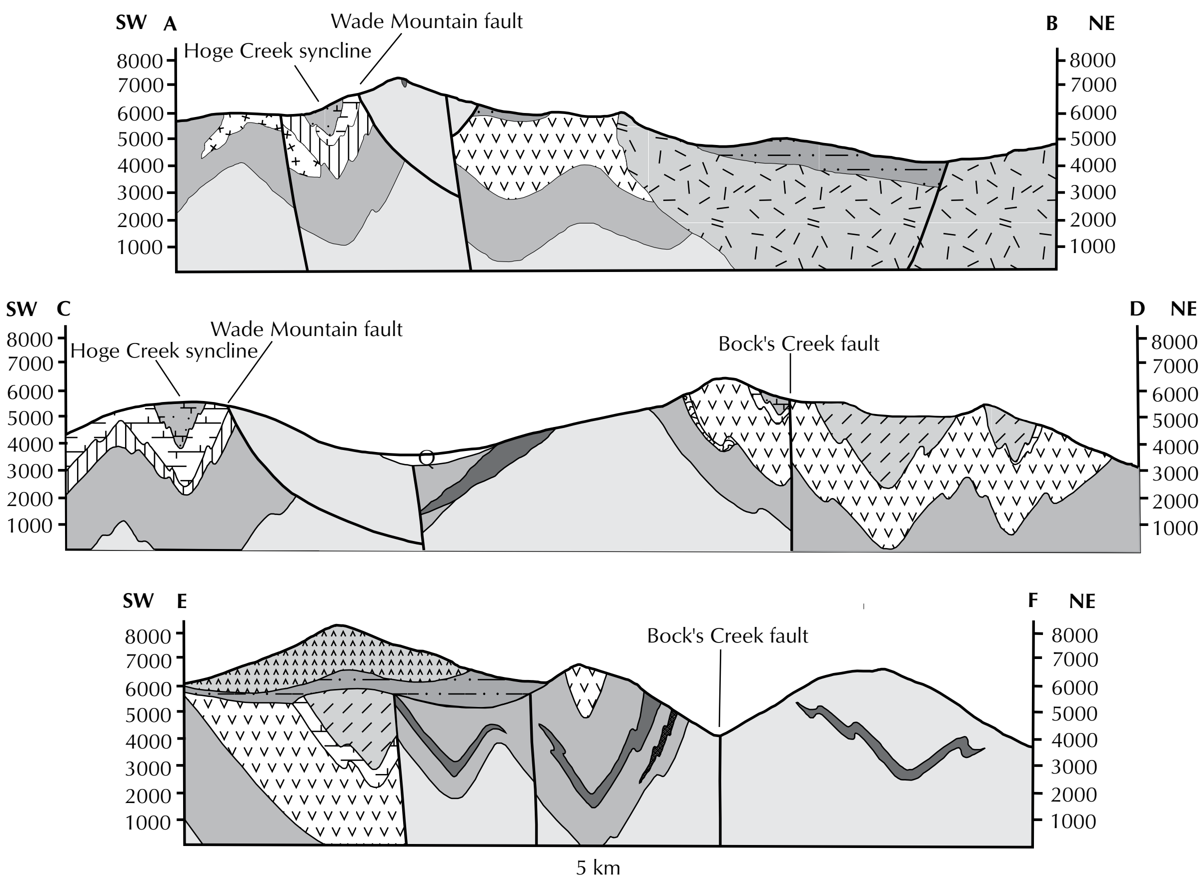

Figure 12. *Schematic geologic cross-sections from the Duke River map area. (Locations of sections and pattern fills are shown in Figure 2.*

Pre-Middle Triassic

There is evidence for Pre-Middle Triassic contraction throughout the Duke River map area, but it is difficult to fully decipher because of intense, younger overprinting structures. Stratigraphic relationships reveal some indication that deformation involving uplift of the Paleozoic units occurred prior to deposition of the Triassic strata.

Read and Monger (1976) describe an unconformable contact between the Hasen Creek Formation and a gabbro body just west of the Duke River map area. At every other location where the base of the Hasen Creek Formation is exposed, outside of faulted contacts, the Station Creek Formation is preserved underlying the sedimentary unit. The lack of any Station Creek Formation below the Hasen Creek Formation may suggest local uplift and erosion of the Station Creek Formation prior to, or during, deposition of the Hasen Creek Formation.

To date, no Early Triassic stratigraphy has been identified anywhere within the Kluane Ranges. The absence of stratigraphy of this age could be the result of uplift and erosion that may have taken place prior to deposition of the Hoge Creek succession.

Finally, at two localities in the adjacent Quill Creek map area, tightly folded Hasen Creek sedimentary strata appear to be unconformably overlain by Nikolai formation volcanic rocks (Israel and van Zeyl, 2004).

Post-Triassic pre-mid-Cretaceous

Deformation during the post-Triassic to pre-mid-Cretaceous time appears to represent the main contractional event to affect the Kluane Ranges. Effects of this event can be observed throughout the Duke River map area and are characterized by northwest-southeast-trending, upright to locally overturned, tight to isoclinal folds and southwest-directed thrust faults. The Wade Mountain fault is a major southwest-directed thrust/reverse fault that places rocks of the Station Creek Formation over Mesozoic strata (Figs. 12, 13). The footwall is tightly folded to form the Hoge Creek syncline with tight chevron folds developed within the McCarthy Formation. Movement along the Bock's Creek fault is not well constrained; tightly folded Tatamagouche succession and Nikolai formation may indicate at least some contractional deformation (Fig. 2, 12). The Duke River fault appears to place metamorphic rocks of the Alexander Terrane over the relatively unmetamorphosed rocks of Wrangellia Terrane. Little information on the

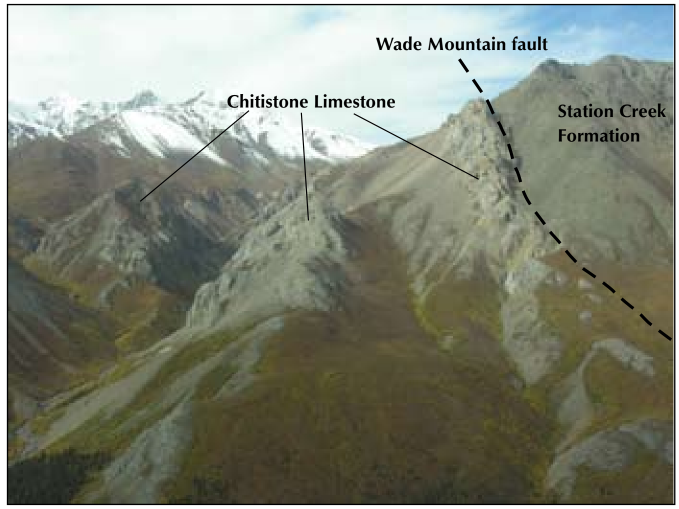

Figure 13. *Aerial view looking west towards the Wade Mountain fault.*

kinematics along the Duke River fault exists outside of recognizing strike-slip related lineations along the fault surface (Read and Monger, 1976). Read and Monger (1976) speculate that K-Ar dates in the eastern Alexander Terrane do not reflect large vertical movement of the terrane. It should be noted that some of the folds in the Quill Creek area, and locally, within the Hoge Creek syncline, are overturned to the northeast, and large northeast-directed thrust faults are also present to the northeast of the Duke River map area (Israel and van Zeyl, 2004). Timing of the contractional event is poorly constrained; it must be older than the Kluane Ranges suite, as these intrusions apparently do not show effects of this deformation; and must be at least as young as the Tatamagouche succession, as it exhibits evidence for the deformation, and may be as young as Hauterivian (Read and Monger, 1976). As with earlier deformation, many of the faults and folds that can be attributed to this event have been reactivated or overprinted by younger deformation.

Post-mid-Cretaceous

The two largest structures in the immediate vicinity of the Duke River area are the Denali and Duke River faults (Fig. 1). The Denali Fault occupies the Shakwak valley, immediately northeast of the Duke River area and is believed to have accommodated ~370 km of right-lateral displacement some time between mid-Cretaceous and the present (Lowey, 1998). The fault extends from northwestern British Columbia, through the Yukon Territory and into central Alaska. It is a major terrane-bounding, presently active, structure, which separates

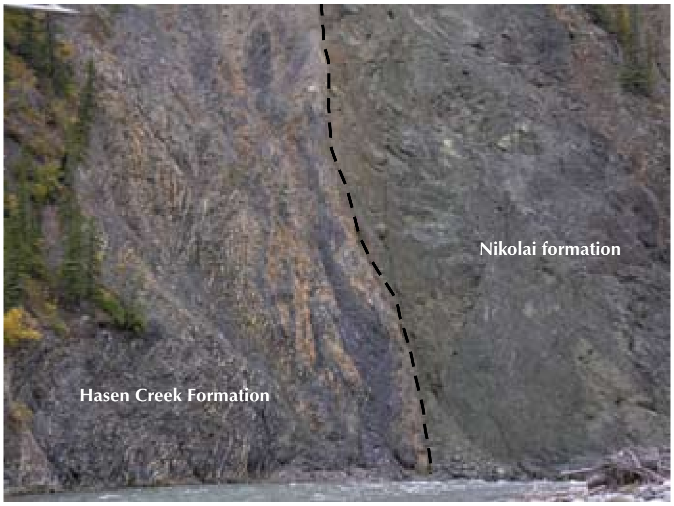

Figure 14. *Steeply dipping fault placing Hasen Creek Formation next to the Nikolai formation.*

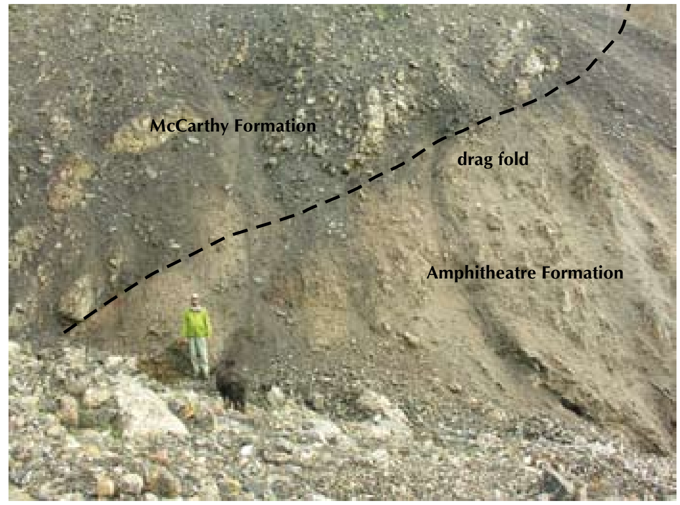

Figure 15. *Tertiary contractional fault represented by Triassic McCarthy Formation thrust over the Amphitheatre Formation. Note drag folds in the Amphitheatre Formation.*

Wrangellia Terrane from the Windy-McKinley and Nisling terranes, and the Coast Plutonic Complex (Fig. 1).

Only small segments of the Duke River fault outcrop in the map area (Fig. 2). The Duke River fault is the bounding fault between Wrangellia and Alexander terranes. It cuts through the entire southwest Yukon and continues into Alaska as the Totschunda Fault, an active splay off the Denali Fault. The fault has been described as a thrust fault that places rocks of the Alexander Terrane over Wrangellia (Muller, 1967), or alternatively, as a remnant of a megathrust that transported Wrangellia to the east overtop of the Alexander Terrane (MacKevett and Jones, 1975). Regardless of the earlier history of the Duke River fault, it has certainly been active as a late-Mesozoic through Cenozoic strike-slip fault (Read and Monger, 1976; Trop *et al.*, 2004). It deforms rocks as young as Miocene age, and earthquakes along the northwesternmost portion of the fault attests to its current active state.

Numerous, steeply dipping faults that are related to movement along the Denali and Duke River faults dissect the map area into northwest-trending fault blocks (Figs. 12, 14). Bock's Creek fault is a map-scale structure that runs the length of the Duke River map area, offsetting Paleozoic and Mesozoic stratigraphy. It cross-cuts many older, steeply dipping faults and has several smaller splays along its length. Gouge and breccia define many of the fault zones, indicating that the deformation at the level exposed was brittle. Large thrust/reverse faults have all been reactivated to some degree, exhibiting nearly horizontal stretching lineations and slickenside fibres. Fault-bound basins that are the sites of deposition of the Amphitheatre Formation are interpreted as either pull-apart or compressional basins caused by the partitioning of strain between the Denali and Duke River faults (Ridgway and DeCelles, 1993). Thrust faults, associated with deformation along the Denali and Duke River faults, place McCarthy Formation over top of the Amphitheatre Formation and folds the Wrangell Lavas (Fig. 15).

MINERALIZATION

Several mineral occurrences are found within the Duke River area and are associated with many different deposit types (Fig. 2, Table 1). Exploration in the area began in the mid-1950s after completion of the Alaska Highway. Since that time, the majority of exploration has centred on nickel-copper-platimum group element (PGE) mineralization hosted in intrusive bodies of the Kluane mafic-ultramafic complex. In 1994, Inco Limited staked the area located between Copper Joe Creek (called Halfbreed Creek on many maps) and Congdon Creek in the southeast portion of the Duke River area. For the next three years, Inco Limited completed mapping programs, lithogeochemical and silt sampling, and geophysical surveys. Massive sulphide showings were found over an area of ~3.6 km at the base of the Spy Sill (Yukon MINFILE 115G 003, Deklerk and Traynor, 2005[2]). Grab samples collected from the contact between the ultramafic body and the Hasen Creek Formation assayed up to 3.1% Ni,

[2]*All Yukon MINFILE occurrences are from Deklerk and Traynor (2005).*

Table 1. *Yukon MINFILE occurrences within the Duke River area (Deklerk and Traynor, 2005).*

Yukon MINFILE number	Name	Status	Commodity
115G 003	Congdon	showing	Cu-Ni
115G 005	Dickson	prospect	gabbroid Cu-Ni
115G 006	Destruction	prospect	gabbroid Cu-Ni
115G 007	Halfbreed	unknown	gabbroid Cu-Ni
115G 008	Squirrel	unknown	gabbroid Cu-Ni
115G 009	Windgap	prospect	coal
115G 010	Duke	showing	Asbestos
115G 011	Hoge	prospect	coal
115G 012	Amphitheatre	showing	coal
115G 013	Wade	showing	gabbroid Cu-Ni
115G 014	Amp	anomaly	porphyry Cu-Mo-Au
115G 015	Cork	drilled prospect	porphyry Cu-Mo-Au
115G 016	Glen	drilled prospect	gabbroid Cu-Ni
115G 017	Burwash	drilled prospect	Besshi MS Cu (Zn)
115G 018	Nelms	unknown	unknown
115G 084	Bock	showing	gabbroid Cu-Ni
115G 086	Gypsum	showing	gypsum
115G 092	Biczock	anomaly	paleoplacer
115G 098	Tony	showing	gabbroid Cu-Ni
115G 099	Kluane, Duke S	showing	gabbroid Cu-Ni

2.8% Cu, 0.2% Co, 3.1 g/t Pt, 1.4 g/t Pd and 1.0 g/t Au (Yukon MINFILE 115G 003). Several other ultramafic bodies are present in the Duke River area, with the largest being the Tatamagouche complex which outcrops along the Duke River. After extensive study of the entire Kluane mafic-ultramafic complex, Hulbert (1997) considered the Tatamagouche complex to have great potential for significant Ni-Cu-PGE mineralization.

Copper, molybdenum and gold mineralization is associated with the Kluane Ranges suite and the Tkope suite near Burwash Creek (Yukon MINFILE 115G 014 and 115G 015, respectively; Table 1). Drilling on the property (Yukon MINFILE 115G 015) by a syndicate of several companies in 1970, returned low values of copper and molybdenum.

Coal is found at several localities within the Amphitheatre Formation (Yukon MINFILE 115G 009, 115G 011 and 115G 012). At each locality, coal seams up to several metres thick occur in tightly folded sediments. Coal from Yukon MINFILE 115G 012 occurrence was reportedly mined very briefly in 1950. In 1985, Noranda Inc. investigated anomalous gold values in silt at the Biczok property (Yukon MINFILE 115G 092) and concluded that the Amphitheatre Formation is likely a paleoplacer deposit.

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