Overview of Yukon Geology

by

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Introduction

Yukon is located in the northern part of the North American Cordillera, the mountainous backbone of the western part of the continent. Like most of the Cordillera, Yukon is composed of rocks that record more than a billion years of Earth history. These document the evolution of the western margin of Ancestral North America (Laurentia) and of the various displaced terranes that were accreted to it since late Paleozoic.

The northwest-striking Tintina fault is one of the most prominent physiographic and geologic feature in Yukon. It is a dextral strike-slip fault with about 430 km of Paleogene displacement. It generally separates rocks of Ancestral North American affinity to the northeast from those of the allochthonous Intermontane terranes to the southwest; except in southeast Yukon, where the Tintina fault has shuffled this order and the allochthonous Yukon-Tanana and Slide Mountain terranes lie northeast of the fault, and parautochthonous rocks of Cassiar terrane underlie the Pelly Mountains to the southwest.

The Intermontane terranes are mainly comprised of magmatic arc rocks and related sedimentary deposits that fringed western Laurentia between mid-Paleozoic and early Mesozoic. They envelop more exotic oceanic rocks of Cache Creek terrane in south-central Yukon, which includes elements of Tethyan affinity. The Intermontane terranes are bounded to the southwest by the northwest-striking Denali fault, an active dextral strike-slip fault with more than 400 km of displacement, that separates them from the Insular terranes. The Insular terranes consist of continental fragments and volcanic arc rocks that contain exotic elements of Baltican and Siberian affinities.

In north Yukon, structures along the northeast-striking Porcupine lineament juxtapose rocks of the Ancestral North American margin with those of the Arctic-Alaska terrane to the northwest. Arctic Alaska is a composite terrane which includes Neoproterozoic and Paleozoic elements of Baltican-Siberian affinities, as well as less exotic northern Laurentian rocks.

Cretaceous and younger, mainly post-accretionary plutonic suites intrude part of the Laurentian margin strata and the Intermontane and Insular terranes in southern Yukon. These represent a succession of continental magmatic arcs and related back-arc environments that record the Cretaceous-Paleogene convergence of the various terranes.

The various terranes and plutonic suites that make up Yukon geology are host to a wide range of base and precious metal deposits. Successor basins that developed during

Jurassic to Paleogene terrane convergence in the northern Cordillera have hydrocarbon potential.

Ancestral North America (Laurentia)

Layered rocks that underlie eastern Yukon and British Columbia and western NWT were deposited on the flank of western Laurentia, a craton whose exposed core is the Canadian Shield. Laurentia coalesced around 1.84 billion years ago and its stability has allowed preservation of one of the world's lengthiest sedimentary record, now observed in uplifted strata along the eastern side of the Cordilleran mountain belt from California to east-central Alaska. The Proterozoic part of this record (older than 542 Ma) is deduced from 'inliers' (windows eroded through the covering Paleozoic formations).

The oldest sedimentary strata in Yukon, the 13 km-thick **Wernecke Supergroup**, consist of two siliciclastic sediment-to-carbonate cycles deposited either in a gentle subsiding basin between cratons, or upon a broad continental shelf attached to Laurentia. Volcanoes erupted atop the sediments 1700 million years ago, but their existence is known only from remnants that collapsed into pits formed by gaseous explosions from great depth (the Wernecke breccias; Thorkelson *et al.,* 2005).

About 1320 Ma, crustal extension was accompanied by basalt intrusions (dykes, sills and pillow lavas near Hart River). Upon the eroded surface was deposited the **Pinguicula Group**, a 2.5 km-thick succession of sandstone interbedded with dolostone, siltstone and shale older than 1270 Ma. The rock record of western Laurentia is blank for the next 200 million years. Shortly after 1000 Ma, a complex succession of carbonate, sandstone and interbedded siltstone and shale constitute the **Mackenzie Mountains Supergroup** in the east (Aitken and McMechan, 1991), and the partly correlative **Fifteenmile Group** in western Yukon. Sedimentary environments in both units indicate a lateral transition from shallow-water carbonate to deeper water shale to the northwest. Furthermore, detrital zircon grains in the sandstone are derived from rocks crystallized during the Grenville orogeny, and are thought to have been transported to the northwest by large intercontinental rivers with sources in southern Laurentia.

Interlaced transcurrent faults that underlie the present-day Snake River drainage were active about 900 Ma; they may have cause regional folding (the Corn Creek orogeny) and local uplift indicated by a low-angle unconformity beneath the **Callison Lake Dolostone** in the southern Ogilvie Mountains.

The supercontinent Rodinia, of which Laurentia had been part since about 1300 Ma, began to break up about 850 Ma. Basalt volcanism and 778 Ma sills are found in the Mackenzie Mountains, Northwest Territories. At that time this part of Laurentia lay at equatorial latitudes, and the red sandstone, white gypsum (evaporite), and shallow water limestone of the **Coates Lake Group** indicate a hot and dry climate prevailed. The southern Ogilvie Mountains reveal a regional-scale syn-sedimentary fault, which is over-stepped by submarine to subaerial volcanism of the **Mount Harper Group**. These are in turn capped by 718 Ma dacite, coincidental with the Franklin dike swarm in northern

Laurentia and domal uplift beneath the western Arctic (Macdonald *et al.,* 2010, and references therein), and submarine glacial deposits of the Sturtian global glaciation. The glaciogenic **Rapitan Group** (Eisbacher, 1985) is widely distributed in the Proterozoic inliers, and in most places is overlain by layers of sedimentary iron (including Crest Iron) and precipitation of a thin, regionally extensive cap carbonate. Blue-green algae and macroscopic life of the Ediacaran biota occur in sediments deposited between glaciations, and these are overlain by siltstone and carbonate of the upper **Windermere Supergroup**.

About 635 million years ago part of the continental shelf of Laurentia drifted away, and a passive margin (also known as the Cordilleran miogeocline) accumulated sediment until about 400 Ma (Middle Devonian period). The continental shelf of the **Mackenzie Platform** remained stable for much of the Paleozoic in northern Yukon, with a steep southern edge north of both Dawson and Mayo developed by at least Middle Cambrian. This abrupt platform to basin transition controlled later development of the Dawson thrust during Mesozoic contraction. In contrast, the early Paleozoic platform edge in eastern Yukon was gentle and oscillated until the end of the Early Ordovician. Intermittent early Paleozoic extension along southern Mackenzie and Macdonald platforms led to development of the Redstone arch in the Mackenzie Mountains, and of embayments in the platform edge along the NWT-Yukon and Yukon-BC borders (Cecile *et al.,* 1997).

The Yukon terrane map shows the distribution of platforms and adjacent Selwyn basin as indicated by deposits of Middle Ordovician age. Slow subsidence of the Mackenzie and Macdonald platforms accommodated the deposition of thick carbonate units, the most prominent being the widespread **Bouvette dolostone** in northern Yukon (Morrow, 1999) and the **Sunblood Formation** in eastern Yukon. In the northern Pelly Mountains of central Yukon lies a 60 km wide sliver of thick carbonate formations, the **Cassiar platform (or terrane)**. It is a fragment of the continental margin shunted 430-490 km northwest by the Tintina fault.

The **Selwyn basin** is floored by a thick succession of mostly coarse sand, overlain by thin limestone and green and maroon shale of the **Hyland Group** (Gordey and Anderson, 1993). In southern Yukon and adjacent NWT, these rocks pass into the Cambrian **Vampire Formation,** which upslope overlaps limestone at the platform edge, and the **Gull Lake Formation** with minor submarine basalt. A Cambro-Ordovician transgressive sequence consists of silty-laminated limestone of the **Rabbitkettle Formation** with at least one sand-dominated depositional wedge derived from the east – the **Crow Formation** (Pigage, 2009). Episodic submarine effusions of alkalic basalt occur near the edge of the basin in the Faro area, in a stagnant rift along the Yukon-NWT border (the Misty Creek embayment) and in the southern Ogilvie Mountains. Their greatest thickness is at the northern edges of the Selwyn basin, suggesting that this is a long-lived, crustal-scale boundary. From Late Ordovician through Early Devonian, black siliceous mudstone, chert and siltstone of the **Road River Group** were deposited in the basin (Cecile and Norford, 1991), locally punctuated by metal-rich brines and seafloor springs which precipitated stratiform zinc-lead deposits in the Anvil Range and Howards Pass area. The Richardson Mountains of northern Yukon expose uplifted basinal sediments of similar age.

About 390 Ma (Middle Devonian period) the sedimentation pattern in Yukon changed abruptly. Sea level rose so that the coastline migrated eastward and sheets of black shale and siltstone, with lenses of sandstone were deposited in eastern and northern Yukon (Gordey, 1991). Selwyn basin in central Yukon was uplifted and eroded, producing thick beds of chert-pebble conglomerate (**Earn Group**) that funneled eastward along possible submarine channels to Macmillan Pass, where barite and zinc-lead deposits precipitated above seafloor fissures. Concurrently northeastern Yukon was inundated by pulses of sandstone and mud shed from a landmass that occupied where the Arctic Ocean and Beaufort Sea are today. During the Carboniferous period river deltas flooded the shallow marine environment, depositing the sandy **Mattson Formation** in southeast Yukon and the **Keno Hill quartzite** in the southern Ogilvie Mountains.

From Pennsylvanian through Early Jurassic (318-178 Ma) a platform environment in eastern and northern Yukon accumulated thin carbonate, sandstone, and green cherty shale including the **Mount Christie** and **Fantasque formations**, respectively overlain by brown sandy shale of the **Jones Lake, Grayling-Toad formations** respectively. Only isolated occurrences of these deposits remain, because beginning in Middle Jurassic time the passive margin succession was uplift and telescoped eastward as continental and oceanic terranes accreted to the western margin of North America.

Arctic Alaska terrane

The Arctic Alaska terrane is a composite terrane that underlies the Seward Peninsula, the Brooks Range and North Slope of Alaska, and the northernmost Yukon Territory. In northern Yukon, the North Slope subterrane underlies the British Mountains and extends southward to the Porcupine River and northward beneath the Beaufort Sea.

The tectonic history of the Arctic Alaska terrane is not clearly understood as it is complicated by several deformation events. Despite these challenges, a general understanding is emerging. Paleontological evidence suggests that the terrane developed in early Paleozoic as an isolated crustal fragment originally located between the Siberian and Laurentian cratons (ancestral Eurasian and North American continents respectively; Dumoulin *et al*., 2002). Plate convergence along northern Laurentia during the early to mid-Paleozoic resulted in the progressive collision and suturing of exotic terranes to the continent. The Arctic Alaska terrane (specifically the North Slope subterrane), is thought to have collided with northern Laurentia in the Devonian (e.g., MacDonald *et al*. 2009; Dumoulin *et al*., 2000; Moore *et al*., 2007; and Lane, 2007), associated with the Early Devonian Romanzof orogeny (Lane, 2007).

The North Slope subterrane consists of a great thickness and variety of sedimentary rocks and minor igneous rocks ranging in age from Neoproterozoic to Devonian. The oldest known are a succession of 700 million year old limestone, siltstone, slate and chert that form the core of the British Mountains. These sediments were deposited on a broad continental shelf known as the Franklinian margin and were overlain during the latest Proterozoic and Early Cambrian by a thick succession of marine sand and silt now assigned to the **Neruokpuk Formation** (Brooks and Lane, 2011). From Early Ordovician to Early Devonian, the region became a basin in which shale, chert, and limestone were deposited (Lane, 2007). Localized submarine volcanism was also active during Cambrian-Ordovician time. Following the Early to Middle Devonian accretion of the North Slope subterrane and the Romanzof orogeny, uplifted strata were eroded and onlapped by a sub-Mississippian unconformity observed throughout the region. Post-collision melting of the thickened crust resulted in Devonian granitic intrusions exposed at Mount Sedgewick, Mount Fitton, Hoidahl Mountain and in the Old Crow Range, as well as in northern Alaska (Lane, 2007). Mississippian and later strata that overlie the North Slope subterrane are associated with the ancestral continental shelf of North America.

The Intermontane terranes

The Intermontane terranes underlie much of the physiographic Yukon Plateau of western and south-central Yukon. They include the Slide Mountain, Yukon-Tanana, Quesnellia, Stikinia and Cache Creek terranes. All of these terranes, with exception of the Cache Creek terrane, originated in the peri-Laurentian realm – within eastern Panthalassa (or proto-Pacific ocean) but in geodynamic tie with the western edge of Laurentia (Colpron *et al.*, 2007). They represent a mid- to late Paleozoic marginal ocean basin (Slide Mountain) and a series of mid-Paleozoic to early Mesozoic nested arc complexes (Yukon-Tanana, Quesnellia, Stikinia). The Cache Creek terrane stands as an anomaly with its predominance of oceanic rocks, occurrences of high pressure/low temperature metamorphic assemblages, and limestone blocks with exotic Early Permian fusilinid and coral faunas of Tethyan (Asian) affinity (Ross and Ross, 1983; Stevens and Belasky, 2009).

In Yukon, the Intermontane terranes have an overall semi-concentric distribution, with the Cache Creek terrane occupying the centre, being surrounded by progressively older rocks of Quesnellia, Stikinia and Yukon-Tanana terranes. This overall distribution of terranes has been ascribed to oroclinal entrapment of the Cache Creek terrane by Quesnellia and Stikinia in Early Jurassic (Mihalynuk *et al.*, 1994, 2004).

Yukon-Tanana and Slide Mountain terranes

The Yukon-Tanana and Slide Mountain terranes respectively represent a mid- to late Paleozoic continental arc system and a coeval back-arc basin that separated the Yukon-Tanana arc from the western margin of Laurentia between Late Devonian and Early to Middle Triassic (Nelson *et al.*, 2006). The Yukon-Tanana terrane comprises a lower assemblage of metamorphosed sedimentary and minor volcanic rocks (Snowcap assemblage) unconformably overlain by three distinct sequences of predominantly arc metavolcanic rocks and associated metasedimentary rocks – the Finlayson, Klinkit and Klondike assemblages (Colpron *et al.*, 2006).

The **Snowcap assemblage** consists mainly of a heterogeneous assemblage of psammitic schist, quartzite, dark gray carbonaceous schist, calc-silicate rocks and marble, and locally amphibolite, greenstone, and ultramafic rocks. These rocks are commonly intruded, and locally thoroughly injected by strongly foliated and lineated Late Devonian to Early Mississippian tonalite, granodiorite, and granite bodies that represent subvolcanic intrusions to overlying arc rocks of the Finlayson and Klinkit assemblages. Rocks of the Snowcap assemblage are typically polydeformed and metamorphosed to amphibolite facies and commonly occupy a low structural level in the Yukon-Tanana terrane. They are inferred to represent a rifted fragment of the western Laurentian margin, possibly representing distal facies of the Neoproterozoic – lower Paleozoic continental margin (Piercey and Colpron, 2009).

The **Finlayson assemblage** is widespread and characteristic of the Yukon-Tanana terrane. It comprises a variety of metavolcanic and metasedimentary rocks of Late Devonian to Early Mississippian age, and representing arc and back-arc environments (Colpron *et al.*, 2006; Piercey *et al.*, 2006). Rocks of back-arc affinity occur mainly in the Finlayson Lake district of southeast Yukon where they are host to volcanogenic massive sulphide mineralization (*e.g.*, Kudz Ze Kayah, Wolverine) (Hunt, 1997; Murphy *et al.*, 2006; Peter *et al.*, 2007). Back-arc facies are dominated by bimodal metavolcanic rocks associated with fine-grained carbonaceous metaclastic rocks. Southwest of Tintina fault, the Finlayson assemblage comprises mostly intermediate to mafic metavolcanic and metavolcaniclastic rocks of arc affinity, and fringing metasedimentary rocks (Colpron *et al.*, 2006). Concurrent basinal facies (carbonaceous phyllite, quartzite and chert) are found in western Yukon and adjacent Alaska (Nasina), and in southern Yukon and northern BC (Swift River). They may represent amagmatic extensions of the back-arc environment.

Arc and back-arc volcanism of the Finlayson assemblage was coeval with intrusions of the Grass Lakes and Simpson Range plutonic suites. The **Grass Lakes plutonic suite** (ca. 365-357 Ma) comprises mainly foliated, coarse-grained, K-feldspar augen metagranite and is primarily found in the Finlayson Lake district and in western Yukon and adjacent Alaska (Piercey *et al.*, 2006). The slightly younger **Simpson Range plutonic suite** (ca. 355-345 Ma) is more widespread in the Yukon-Tanana terrane. It consists of foliated to strongly foliated, fine- to medium-grained metagranodiorite, metadiorite and metatonalite, with rare metagranite.

The Middle Mississippian to Lower Permian **Klinkit assemblage** includes intermediate to mafic metavolcaniclastic and metavolcanic rocks, and prominent, locally fossiliferous marble. It is best preserved in the southern part of the Yukon-Tanana terrane. Rocks of the Klinkit assemblage unconformably overlie older parts of the terrane (Snowcap and Finlayson assemblage). Its base is locally marked by a polymictic conglomerate containing foliated clasts of underlying lithologies. Rocks of the Klinkit assemblage are invariably less deformed and metamorphosed than underlying strata. The Klinkit assemblage has been correlated with late Paleozoic rocks that make up the basement to Mesozoic Quesnellia in central and southern British Columbia (Simard *et al.*, 2003), implying that Yukon-Tanana terrane constitutes at least part of the basement to

Quesnellia. Plutonic rocks of the **Tatlmain suite** (ca. 340-336 Ma) are coeval in part with arc volcanic rocks of the Klinkit assemblage. The Tatlmain suite comprises mainly variably foliated to unfoliated, coarse-grained granite, granodiorite and minor gabbro.

The youngest arc succession of Yukon-Tanana terrane is the Middle to Upper Permian **Klondike assemblage**. It is mainly restricted to the Klondike Plateau of western Yukon, south of Dawson City. It consists mainly of strongly foliated quartz-muscovite schist (felsic metavolcanic rocks) of calc-alkaline affinity, intercalated with minor intermediate to mafic metavolcanic rocks (Mortensen, 1990, 1992; Ryan and Gordey, 2004). Comagmatic plutons of the **Sulphur Creek suite** (ca. 264-252 Ma) are composed mainly of K-feldspar augen metagranite. They generally occur in close proximity to exposures of the Klondike assemblage, but small intrusive bodies of this age are also found in the Finlayson Lake district of southeastern Yukon and on either sides of the Yukon-British Columbia boundary.

Late Devonian to Permian arc magmatism in the Yukon-Tanana terrane was coeval with deposition of oceanic rocks in the Slide Mountain terrane to the east. In Yukon, the **Slide Mountain assemblage** is best preserved in the Finlayson Lake district, where it includes: 1) Mississippian to Lower Permian carbonaceous phyllite, chert, greenstone, quartzofeldspathic grit and conglomerate, and minor felsic metavolcanic rocks (Fortin Creek group); 2) Lower Permian chert, argillite and basalt (Campbell Range formation); and 3) Lower to Middle Permian limestone and quartzite (Gatehouse formation) (Murphy *et al.*, 2006). Gabbro and ultramafic complexes of Early Permian age are commonly associated with rocks of the Slide Mountain assemblage. Rocks of the Slide Mountain terrane are interpreted to represent a back-arc, marginal ocean that developed behind the Yukon-Tanana arc between Early Mississippian and Middle Permian (Colpron *et al.,* 2007; Nelson *et al.*, 2006). The Slide Mountain ocean is inferred to have closed in Middle to Late Permian by westward subduction beneath the Yukon-Tanana terrane. Records of Permian subduction are found in the belt of ca. 270 Ma eclogites that occurs along the eastern edge of Yukon-Tanana (Erdmer *et al.*, 1998) and in arc magmatism of the Klondike assemblage (to the west).

Final closure of the Slide Mountain ocean is indicated by a sequence of fine-grained siliciclastic rocks of Middle to Late Triassic age that overlaps Yukon-Tanana and Slide Mountain terranes, as well as rocks of the western Laurentian margin (Beranek, 2009).

Stikinia and Quesnellia

Stikinia and Quesnellia are two of the most prominent arc terranes of the Canadian Cordillera. They are both characterized by Triassic augite (plagioclase) -phyric volcanic rocks overlying locally exposed, mid to late Paleozoic volcano-sedimentary sequences. In British Columbia, these twin terranes are typically distinguished by their occurrence on either side of the Cache Creek terrane. In Yukon, the Cache Creek terrane only extends to the latitude of Whitehorse. To the north, the distinction between Stikinia and Quesnellia is difficult; they are juxtaposed along the Teslin fault (Colpron, 2011).

Quesnellia in Yukon extends from Teslin Lake northwesterly to the Pelly River in central Yukon. It comprises the Paleozoic Boswell assemblage and the overlying Upper Triassic-Lower Jurassic arc volcanic rocks of the Semenof formation. The **Boswell assemblage** consists of basalt (MORB, EMORB) and limestone of the Upper Devonian to Lower Mississippian Moose formation, and Upper Mississippian to Lower Permian arc volcanic, volcaniclastic and sedimentary rocks (including Pennsylvanian-Permian fossiliferous limestone) of the Boswell formation (Simard, 2003). A Pennsylvanian tonalite pluton intrudes rocks of the Moose formation at the northern end of the belt (Colpron, 2011). These rocks are unconformably overlain by Upper Triassic-Lower Jurassic volcanic and volcaniclastic strata of the **Semenof formation**. Carnian-Norian limestone occurs locally towards the north end of this belt. Paleozoic rocks of the Boswell assemblage vary from weakly foliated, sub-greenschist facies rocks in the south, to penetratively foliated, amphibolite facies metamorphic rocks in the north.

The oldest rocks in Stikinia, southwest of the Teslin fault, are the metamorphosed volcanic, volcaniclastic and minor carbonate rocks of the upper Paleozoic **Takhini assemblage**, exposed west of Whitehorse (Hart, 1997). Mesozoic Stikinia is represented by volcanic and sedimentary strata of the Middle Triassic Joe Mountain Formation and the Upper Triassic Lewes River Group (Hart, 1997). The **Joe Mountain Formation** consists of a mafic-ultramafic intrusive complex, basalt and volcaniclastic rocks of Ladinian (Middle Triassic) age. The Upper Triassic **Lewes River Group** includes a lower formation of Carnian augite-phyric basalt, basaltic andesite and volcaniclastic rocks (Povoas formation; informal nomenclature of Tempelman-Kluit, 1984, 2009) and an upper formation of Carnian to Rhaetian epiclastic, volcanogenic sedimentary rocks and limestone (Aksala formation). The Aksala formation includes three mappable members: 1) the Casca member, a Carnian-Norian heterogeneous sequence of lithic sandstone, argillite and conglomerate; 2) the Hancock member, a Norian-Rhaetian reef limestone, including Grey Mountain in Whitehorse and Lime Peak near Lake Laberge; and 3) the Mandanna member, a Rhaetian maroon lithic sandstone, siltstone, mudstone and minor conglomerate of fluvial to tidal origin. These sedimentary rocks record the waning stage of the Lewes River arc.

Late Triassic-Early Jurassic (ca. 205-185 Ma) plutons affiliated with Quesnellia and Stikinia define paired magmatic belts on either sides of the Cache Creek terrane and Whitehorse trough, which merge in central Yukon near the northern apex of Quesnellia/Stikinia. These plutons are well known for their world-class Cu-Au and Cu-Mo porphyry deposits in British Columbia; in Yukon, they are host to Cu-Au-Ag deposits at Minto and Carmacks Copper (Nelson and Colpron, 2007). Late Triassic-Early Jurassic plutons intrude Triassic and older rocks of Stikinia and Quesnellia, as well as the Yukon-Tanana terrane. Their volcanic equivalent in B.C. are the Hazelton and Rossland groups; in Yukon, volcanic products of that age are restricted to pyroclastic rocks intercalated with Lower Jurassic marine sedimentary rocks of the Laberge Group in Whitehorse trough. The Late Triassic-Early Jurassic plutons were intruded during rapid exhumation of the metamorphic infrastructure of the Yukon-Tanana terrane.

Cache Creek terrane

The Cache Creek terrane consists predominantly of oceanic rocks (basalt, chert, argillite, gabbro and ultramafic rocks) of Early Mississippian to Middle Jurassic age, and upper Paleozoic limestone with exotic Tethyan faunas (Gabrielse, 1998; Mihalynuk, 1999). Also present locally in B.C. are Upper Permian-Lower Triassic arc volcanic rocks (Kutcho assemblage). The highly disrupted nature of the Cache Creek terrane and occurrences of Triassic and Middle Jurassic blueschist in B.C. indicate that it represents an accretionary complex, possibly recording more than 6000 km of subduction of Panthalassa (proto-Pacific) lithosphere beneath the Quesnellia-Stikinia arcs.

Whitehorse trough

The Whitehorse trough is a syn-accretionary sedimentary basin that developed during convergence of Stikinia, Quesnellia and the Cache Creek terranes in Early to Middle Jurassic. It comprises up to 3000 m of mainly clastic strata (**Laberge Group**) which in Yukon are divided in two distinct facies: 1) a northern, shallow-marine to fluvial succession of sandstone, conglomerate, shale and coal (Tanglefoot formation); and 2) a southern succession of deep-water turbidite and mass-flow deposits (Richthofen formation). A Pliensbachian (ca. 188-184 Ma) series of pyroclastic deposits (Nordienskiold formation) is common to both environments; it is coeval with the latest pulse of Early Jurassic magmatism flanking the Whitehorse trough to the west and east. Strata of the Laberge Group unconformably overlie Stikinia and Quesnellia, and are possibly correlative with Lower Jurassic clastic rocks of the Cache Creek terrane. Deposition of fluvial, chert-pebble conglomerate, sandstone and coal of the Middle Jurassic to Lower Cretaceous **Tantalus Formation** marks to end of Whitehorse trough.

The Insular terranes

The Insular terranes of southwest Yukon comprise Wrangellia and the Alexander terrane. Both of these terranes are considered exotic to the western Laurentian margin. Current tectonic models suggest that the Insular terranes were accreted as a coherent tectonic block sometime in the Early to Middle Jurassic (McClelland *et al.*, 1992; van der Heyden, 1992; Monger *et al.*, 1994). A Middle Pennsylvanian pluton (ca. 309 Ma), stitches the two terranes together, indicating a shared geotectonic history from at least this time (Gardner *et al.*, 1988).

Alexander terrane

The Alexander terrane in southwest Yukon is composed of three main Paleozoic assemblages: 1) Cambrian to Ordovician mafic volcanic rocks, quartz sandstone, volcaniclastic rocks and minor limestone of the Donjek assemblage; 2) Ordovician to Silurian carbonate and calcareous mudstone and siltstone of the Bullion assemblage; and 3) Devonian to Triassic, carbonate, siltstone, sandstone and minor volcanic rocks of the Icefield assemblage (Dodds and Campbell, 1992).

Recent work on the Alexander terrane in southwest Yukon indicates that these rocks are different that those studied by Gehrels and Saleeby (1987) in southeast Alaska. Therefore, rocks of the Alexander terrane exposed in Yukon and northwestern British Columbia are referred to as the Saint Elias subterrane (Beranek *et al.*, 2011), while those exposed in southeast Alaskan comprise the Craig subterrane.

The **Donjek assemblage** is considered a rift/drift sequence that represents the formation of a back-arc basin that developed into a full-scale spreading centre in the Cambrian to Ordovician. It has been suggested that this piece of Alexander terrane is a rifted fragment of Baltica, that was later transported through the Arctic realm to the western margin of Laurentia (Colpron and Nelson, 2009; Beranek *et al.*, in press). The Craig and Saint Elias subterranes were likely brought together during the Silurian-Devonian Klakas orogeny.

Pennsylvanian to Permian intrusions are found throughout the Alexander terrane in southwest Yukon. These belong to the **Icefield suite** and are mainly quartz-monzonite to syenite in composition. This suite includes the Barnard Glacier pluton that intrudes the boundary between Alexander terrane and Wrangellia (Gardner *et al.*, 1988). A regionally extensive Jurassic (154-149 Ma) suite, the **Saint Elias suite**, also occurs through the Alexander terrane in southwest Yukon. It consists of porphyritic to non-porphyritic (k-feldspar), quartz diorite to granite.

Wrangellia

Wrangellia in southwest Yukon comprises Paleozoic through to mid-Mesozoic volcanic and sedimentary rocks. The oldest stratified rocks of Yukon Wrangellia belong to the **Skolai Group** (Smith and MacKevett, 1970; Read and Monger, 1976), which includes the Station Creek and the Hasen Creek formations. The **Station Creek Formation**, named for the type section in eastern Alaska, include Lower Mississippian (ca. 354 Ma) mafic volcanic rocks overlain by volcanic breccia, tuff and volcaniclastic sandstone. The Station Creek Formation is considered to represent back-arc oceanic crust that was overlain by arc volcanic detritus. Conformably overlying the Station Creek Formation is the Permian **Hasen Creek Formation**, a sequence of conglomerate, sandstone and siltstone turbidites and limestone. The Hasen Creek Formation records sedimentation following cessation of volcanism and subsidence of the Mississippian-Pennsylvanian arc.

A regional unconformity separates the Skolai Group from thin Middle Triassic siltstone locally preserved beneath the regionally extensive Nikolai formation. The **Nikolai formation** comprises a basal conglomerate, overlain by thick accumulations of basalt. The basalt is the hallmark of Wrangellia and is found throughout the terrane from Alaska to Vancouver Island (where it is known as the Karmutsen Formation). The Nikolai volcanic rocks are up to 3000 m thick and consist mainly of subaerial, vesicular to amygdaloidal flows. Rare pillows occur near the base of the formation. The volcanic rocks are overlain, and in some places interlayered, with thick carbonate horizons of the **Chitistone limestone**. This limestone likely represent atoll reefs formed as the volcanic plateau subsided. The carbonate rocks are overlain by deeper marine sedimentary strata of the **McCarthy Formation**.

Voluminous ultramafic intrusions accompanied eruption of the Nikolai basalt. These intrusions include gabbro, pyroxenite and dunite of the **Kluane mafic-ultramafic complex** (Hulbert, 1997). They are interpreted to be part of the feeder system for the overlying Nikolai volcanic rocks and are host to Ni-Cu-PGE deposits. A Late Triassic suite of granodiorite to quartz-diorite has recently been recognized. The significance of these rocks is not well understood but their arc chemistry suggests that there was an active magmatic arc being formed on Wrangellia in the Late Triassic.

In southwest Yukon, the Alexander terrane and Wrangellia are separated by the Duke River fault, a seismically active structure that has a long tectonic history. Recent study of this fault indicates that it is likely a terrane suture that marks the ‘newest’ boundary between the Alexander terrane and Wrangellia, after the two terranes were possibly separated by Triassic rifting.

Overlap assemblages on the Insular terranes

Overlap assemblages found on the Insular terranes include the Jura-Cretaceous Dezadeash Formation, the Oligocene Amphitheatre Formation and the Miocene Wrangell volcanic rocks.

The **Dezadeash Formation** is a thick succession of Upper Jurassic to Lower Cretaceous turbidites, likely formed in a proximal arc setting. Ages of tuffs within the Dezadeash Formation match those of the Saint Elias suite within the Alexander terrane and are likely related.

The Paleocene to Oligocene **Amphitheatre Formation** is a spatially restricted succession of terrestrially derived conglomerate and sandstone. Coal seams are found throughout the succession interlayered with conglomerate and sandstone. The Amphitheatre Formation is interpreted to have been deposited on the Alexander terrane and Wrangellia, in basins developed during deformation along the Denali fault. Both extensional and compressional basins formed along second order structures associated with overall dextral strike-slip deformation (Ridgway *et al.*, 1992). Material from the surrounding terranes forms the fill for the basins. Conglomerate of the Amphitheatre Formation may be a paleoplacer, acting as the source for gold mineralization for more recent placer deposits in the Kluane Ranges.

The **Wrangell volcanic rocks** include Miocene basalt, andesite, volcaniclastic rocks and tuff. These are terrestrially deposited volcanic rocks that are related to subduction of the Pacific plate beneath southern Alaska and Yukon. These volcanic rocks are found to overly both the Alexander terrane and Wrangellia.

The Kluane Schist (undivided metamorphic rocks of the Coast plutonic complex)

The **Kluane Schist** is a monotonous package of biotite, muscovite, quartz schist found in southwest Yukon, just north of the Denali fault. The schist is at the base of a structural stack that includes the Paleocene Ruby Range batholith and the Yukon-Tanana terrane.

The Kluane Schist can be divided into two distinct packages: 1) biotite-rich schist; and 2) muscovite-rich schist. The schists are strongly to very weakly carbonaceous with the amount of carbon increasing to the west. Locally, carbonate-rich layers occur as thin, discontinuous pods. Strongly deformed and altered ultramafic bodies occur locally in the central and northwestern portion of the Kluane Schist. The largest of these, the Doghead Point ultramafic body, has been dated as latest Triassic and is interpreted to represent a sliver of arc basement. The general structural geometry of the Kluane Schist mimics the regional framework with an overall northeast dip of structural elements; however, the internal structural geometry is more complex with at least three phases of folding overprinting the main foliation. Preliminary detrital zircon analyses of quartz-rich layers within the biotite-rich schist suggest that the Kluane Schist is no older than ca. 94 Ma. Metamorphic overgrowths on almost all zircon grains indicate a major thermal event at ~82 Ma. A gneissic unit found structurally above the Kluane Schist has an uncertain geologic affinity, and may represent either migmatitic Kluane Schist or Yukon-Tanana terrane.

The present geologic architecture of southwest Yukon can be attributed to mid-Cretaceous (ca. 82 Ma) southwest-verging (present day coordinates) thrusting of Yukon-Tanana terrane over rocks of the Kluane Schist. This initial juxtaposition of terranes was responsible for the main metamorphic and structural elements found within the Kluane Schist. Progressive deformation during continued southwest-verging compression deformed these elements into the general northeast-dipping map patterns observed today. Locally the main northeast-dipping structures have been modified by deformation related to later movement along the Denali fault. Intrusion of the Ruby Range batholith occurred along the structural boundary between the Kluane Schist and the Yukon-Tanana terrane, likely near the waning stages of southwest-directed compression in Early Paleocene time.

The Outboard terranes

The outboard terranes include the Chugach and Yakutat terranes. The farthest outboard of these terranes, the **Yakutat terrane**, consists of Cretaceous flysch and mélange and Paleogene igneous rocks and basaltic volcanic rocks (Plafker, 1987). The Yakutat terrane is a portion of the Pacific plate that was excised from the western margin of the Canadian Cordillera, sometime in the Oligocene. The Cretaceous rocks are considered to be part of the accretionary prism formed at the western boundary of North America, while the Paleogene igneous rocks are the result of melts generated during the subduction of the Kula Ridge during the Eocene (Haeussler *et al.*, 2003 and references therein).

The **Chugach terrane** is an accretionary complex that consists of flysch characterized by sandstone, argillite and siltstone interpreted as turbidites formed as trench-fill in the latest Cretaceous to early Cenozoic (Pavlis and Roeske, 2007, and references therein). It sits structurally above the Yakutat terrane and is juxtaposed next to the Insular terranes across the Border Ranges fault. The Border Ranges fault is considered to be the old subduction zone fault before subduction jumped outboard after the collision of the Yakutat terrane.

Post-accretionary magmatism

Cretaceous and younger magmatism is superposed on the amalgamation of terranes that form the northern Cordillera. It includes a series of distinct plutonic suites that cut across tectonic elements and occurs from near the present continental margin as far as 700 km inboard into Selwyn basin (Hart *et al.*, 2004). Extrusive rocks are associated with some of these suites. The youngest magmatic events in Yukon are only expressed by local occurrences of volcanic rocks.

Early Cretaceous (ca. 145-135 Ma) plutonism is restricted to the Insular terranes (**St. Elias suite**) but also locally intrudes the Chugach terrane. By contrast, mid-Cretaceous magmatism is more widespread, occurring in a series of northwest-trending plutonic belts that generally young from southwest to northeast. Southwest of Denali fault, the **Kluane Ranges suite** (ca. 118-108 Ma) intrudes Wrangellia and Alexander terrane, as well as the Dezadeash Formation. They comprise mainly I-type, calc-alkaline plutons. Equivalent plutons in the northern Wrangell Mountains of Alaska are associated with porphyry copper and copper-molybdenum deposits and gold-rich skarns (Hart *et al*., 2004).

Northeast of the Denali fault, metaluminous, calc-alkaline batholiths of the **Dawson Range and Whitehorse suites** (ca. 112-99 Ma) intrude the Intermontane terranes. These plutons generated the numerous Cu-Au-Ag skarns of the Whitehorse Copper Belt (Tenney, 1981) and may be related to some of the gold mineralization found in the Dawson Range. Volcanic rocks of the **Mount Nansen Group** are likely extrusive equivalents of the Dawson Ranges and Whitehorse plutonic suites. Further inboard, the **Cassiar suite** (110-100 Ma) and offset equivalents northeast of Tintina fault, the **Hyland and Anvil suites** (110-96 Ma), comprises mainly peraluminous granite that intrude rocks of the Ancestral North American margin (Cassiar terrane and Selwyn basin) and the Slide Mountain and Yukon-Tanana terranes. These suites are characterized by numerous tungsten±molybdenum skarns and veins, and distal Ag-Pb-Zn veins (Hart *et al.*, 2004). The **South Fork volcanics** form large caldera complexes north of Ross River and are likely related to magmatism of the Anvil suite.

The most inboard of the mid-Cretaceous plutonic suites, the Tungsten, Mayo and Tombstone suites (Hart *et al.*, 2004) are restricted northeast of Tintina faults where they intrude strata of Selwyn basin. The **Tungsten suite** (ca. 97-94 Ma) comprises mainly weakly peraluminous granite and is associated with world-class scheelite skarn deposits, including Mactung and Cantung. The slightly younger **Mayo suite** (95-92 Ma) occurs along the northwest extension of the Tungsten suite. Its plutons have mainly metaluminous compositions and are associated with numerous intrusion-related gold occurrences, including Dublin Gulch and Clear Creek. The **Tombstone suite** (ca. 92-90 Ma) lies at the western end of this belt of mid-Cretaceous plutons, north of Dawson. Plutons of the Tombstone suite are generally of more alkalic compositions, with dominance of monzonite and syenite. They are associated with U-Th-REE mineralization and the gold deposits at Brewery Creek.

Late Cretaceous magmatism is widespread on the Yukon Plateau, between Tintina and Denali faults. It includes small plutons of the **Prospector Mountain suite** (ca. 76-72 Ma) which comprises mainly high-level prophyries and are associated with significant Cu-Au porphyry (*e.g.,* Casino) and epithermal mineralization. The slightly younger **Carmacks Group** (ca. 70-68 Ma) comprises basalt and basaltic andesite of alkalic affinity that probably once covered much of the Yukon Plateau. Northeast of Tintina fault, Late Cretaceous magmatism is limited to the northeast-trending **McQuesten plutonic suite** (ca. 67-63 Ma) which is associated with silver-tin mineralization (Murphy, 1997).

The **Ruby Range suite** (ca. 64-56 Ma) forms the core of the Coast plutonic complex in Yukon. It comprises mainly granodiorite to tonalite and has potential for copper-molybdenum porphyry and epithermal styles of mineralizations (Israel *et al.,* 2011). Slightly younger (ca. 55-48 Ma) peraluminous granites in southwest Yukon are locally host of molybdenum veins. These intrusive rocks are likely the subvolcanic equivalent to the Eocene **Skukum Group**, which includes felsic volcanic rocks near the Mount Skukum gold mine, in the Sifton Range west of Whitehorse, and in the southern Dawson Range.

Volcanism has persisted until geologically recent time in the northern Cordillera. The **Miles Canyon basalt** near Whitehorse was erupted approximately 8 million years ago (Hart and Villeneouve, 1999). Even more recent basaltic volcanism occurs near Fort Selkirk (<3 Ma), Rancheria and Watson Lake.

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