Architecture of pericratonic Yukon-Tanana terrane in the northern Cordillera

J.J. Ryan[1*], A. Zagorevski[2], N.R. Cleven[1], A.J. Parsons[3], and N.L. Joyce[2]

Ryan, J.J., Zagorevski, A., Cleven, N.R., Parsons, A.J., and Joyce, N.L., 2021. Architecture of pericratonic Yukon-Tanana terrane in the northern Cordillera; in *Northern Cordillera geology: a synthesis of research from the Geo-mapping for Energy and Minerals program, British Columbia and Yukon, (ed.) J.J. Ryan and A. Zagorevski; Geological Survey of Canada, Bulletin 610, p. 67-93. https://doi.org/10.4095/326062*

Abstract: West-central Yukon and eastern Alaska are characterized by widespread metamorphic rocks that form part of the allochthonous, composite Yukon-Tanana terrane and parautochthonous North American margin. Structural windows through the Yukon-Tanana terrane expose parautochthonous North American margin in that broad region, particularly as mid-Cretaceous extensional core complexes. Both the Yukon-Tanana terrane and parautochthonous North American margin share the same Late Devonian history, making their discrimination difficult; however, distinct post-Late Devonian magmatic and metamorphic histories assist in discriminating Yukon-Tanana terrane from parautochthonous North American margin rocks. The suture between Yukon-Tanana terrane and parautochthonous North American margin is obscured by many episodes of high-strain deformation. Their main bounding structure is probably a Jurassic to Cretaceous thrust, which has been locally reactivated as a mid-Cretaceous extensional shear zone. Crustal-scale structures within composite Yukon-Tanana terrane (e.g. the Yukon River shear zone) are commonly marked by discontinuous mafic-ultramafic complexes. Some of these complexes represent orogenic peridotites that were structurally exhumed into the Yukon-Tanana terrane in the Middle Permian.

Résumé : Le centre ouest du Yukon et l'est de l'Alaska sont caractérisés par de grandes étendues de roches métamorphiques, qui forment une partie du terrane composite allochtone de Yukon-Tanana et de la marge parautochtone de l'Amérique du Nord. Dans cette vaste région, la marge parautochtone est exposée dans des fenêtres structurales traversant le terrane de Yukon-Tanana, plus spécifiquement dans des complexes à noyau métamorphique formés par distension au Crétacé moyen. Il est difficile de distinguer le terrane de Yukon-Tanana de la marge parautochtone de l'Amérique du Nord, puisqu'ils partagent tous deux la même histoire tardi-dévonienne. Toutefois, des histoires magmatiques et métamorphiques différentes après le Dévonien tardif permettent la distinction des roches du terrane de celles de la marge parautochtone. Plusieurs épisodes d'intense déformation ont masqué la suture entre le terrane de Yukon-Tanana et la marge parautochtone de l'Amérique du Nord. La principale structure les séparant est une faille de chevauchement active du Jurassique au Crétacé, qui a été réactivée par endroits sous forme de cisaillement par extension au Crétacé moyen. Les structures à l'échelle de la croûte présentes dans le terrane composite de Yukon-Tanana (p. ex., la zone de cisaillement du fleuve Yukon) sont habituellement signalées par la présence de complexes mafiques-ultramafiques discontinus. Certains de ces complexes représentent des péridotites orogéniques qui ont été exhumées tectoniquement au sein du terrane de Yukon-Tanana lors du Permien moyen.

---

[1] Geological Survey of Canada, 1500-605 Robson Street, Vancouver, British Columbia V6B 5J3
[2] Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8
[3] Department of Earth Sciences, University of Oxford, South Parks Road, Oxford OX1 3AN, United Kingdom
*Corresponding author: J.J. Ryan (email: jim.ryan@nrcan-rncan.gc.ca)

INTRODUCTION

The North American Cordillera accretionary orogen comprises a collage of terranes that were successively accreted to the western margin of the North America (Laurentia) during the Late Paleozoic to Early Cenozoic (Coney et al., 1980; Gabrielse et al., 1991; Monger and Price, 2002). The Cordilleran Orogen has episodically been in a subduction and/or accretion setting from Late Devonian to recent, wherein episodic deformation, metamorphism, and crustal growth accompanied continued subduction and terrane accretion (Cawood et al., 2009; Nelson et al., 2013). Some of the accreted terranes preserve a Proterozoic to late Paleozoic history that is similar to the Laurentian margin. These terranes have been interpreted to be derived from the Laurentian margin and are referred to as the pericratonic terranes (Colpron et al., 2007; Nelson et al., 2013). The Yukon-Tanana terrane is the largest pericratonic terrane in Yukon (Fig. 1). The Yukon-Tanana terrane, along with the arc-related Quesnellia and Stikinia, and 'oceanic' Slide Mountain and Cache Creek terranes are collectively known as the Intermontane terranes (Monger et al., 1982). Much of the research into these terranes has been driven by their metallogenic endowment, particularly the Paleozoic volcanic-associated massive-sulphide (VMS) deposits of Yukon-Tanana terrane in the Finlayson Lake district (Hunt, 2002; Mortensen et al., 2006; Murphy et al., 2006; Peter et al., 2007) and Mesozoic gold (e.g. Allan et al., 2013) and porphyry mineralization in Stikinia and Quesnellia (e.g. Logan and Mihalynuk, 2014).

This contribution presents key findings from work performed between 2009 and 2018 under the auspices of the Geo-mapping for Energy and Minerals (GEM) Cordillera project, mainly focusing on the Yukon-Tanana terrane and parts of parautochthonous North America. The Yukon-Tanana terrane is exposed from Alaska to British Columbia, however the majority of its exposure is in Yukon. The Cordillera project produced updated regional mapping coverage (Fig. 1) of the McQuesten (Ryan et al., 2010), northern Stevenson Ridge (Ryan et al., 2013a, b), Mount Nansen–Nisling River (Ryan et al., 2016), and Klaza River (Ryan et al., 2018a) areas. The Cordillera project also carried out thematic studies in the Mount Burnham (Staples et al., 2013, 2016); Sylvester allochthon (Ryan et al., 2015), Thirtymile–Wolf Lake (Cleven et al., 2018), and Dunite Peak (Parsons et al., 2017a, b, 2019) regions. Numerous high-resolution geophysical surveys were acquired, compiled, and analyzed in support of mapping activities (*see* Hayward and Ryan, this volume). The present authors herein summarize results of mapping and thematic studies aimed at furthering the understanding of major boundary features, processes, and structures in Yukon. The internal composition of metamorphic and structural domains within the Yukon-Tanana terrane, the significance of the structurally bounded ultramafic complexes, and the relationship with the parautochthonous North American margin are described, and the need to continue re-evaluation of the Yukon-Tanana terrane is highlighted.

A note on the stratigraphic nomenclature

Much of the tectonostratigraphy of Yukon-Tanana terrane and deformed and metamorphosed parautochthonous North American margin rocks are not currently divisible into groups, formations, and suites as per formal stratigraphic code (North American Commission on Stratigraphic Nomenclature, 2005). Instead, by historical convention, regions of broadly similar rocks are included in tectonic assemblages (e.g. Gabrielse et al., 1991). In some cases, this nomenclature is broadly similar to suite, group, and complex in the stratigraphic code; however, in other cases, these assemblages combine unrelated tectonic, magmatic, and stratigraphic units. Continued future research should serve to resolve some of these geological incongruences.

PARAUTOCHTHONOUS NORTH AMERICA

The Paleozoic geology of the western North American Craton is characterized by development of long-lived, shallow-water platforms (Mackenzie, McDonald, Bow, McEvoy) and coeval deep-water basins (Selwyn, Kechika, Richardson; Nelson et al., 2013; Fig. 1). The Cassiar terrane represents a piece of the McEvoy platform that was displaced along the Tintina Fault (Fig. 1; Gabrielse et al., 2006). Parautochthonous North American margin and its displaced portions are in contact with the accreted terranes to the west across a multiply reactivated suture zone, locally known as the Inconnu thrust (Fig. 2; Murphy et al., 2006).

Parautochthonous rocks also occur to the west of the Yukon-Tanana terrane in the Tanana Uplands of eastern Alaska. Here, the parautochthonous North American margin includes the Lake George and Totatlanika assemblages (Hansen and Dusel-Bacon, 1998; Dusel-Bacon et al., 2006, 2017; Staples et al., 2016). These assemblages lack the Late Mississippian to Permian magmatism (<357 Ma) that is characteristic of the Yukon-Tanana terrane (Dusel-Bacon et al., 2006; Dusel-Bacon and Williams, 2009), as such they have been interpreted to represent parautochthonous North American margin rocks that were strongly deformed and metamorphosed in the middle Cretaceous (Staples et al., 2016). The Lake George assemblage and the Delta mineral belt geology are characterized by amphibolite-facies pelite, quartzite, and mafic to felsic igneous rocks (Foster et al., 1994; Dashevsky et al., 2003). Igneous rocks include large intrusive bodies of Late Devonian and Early Mississippian

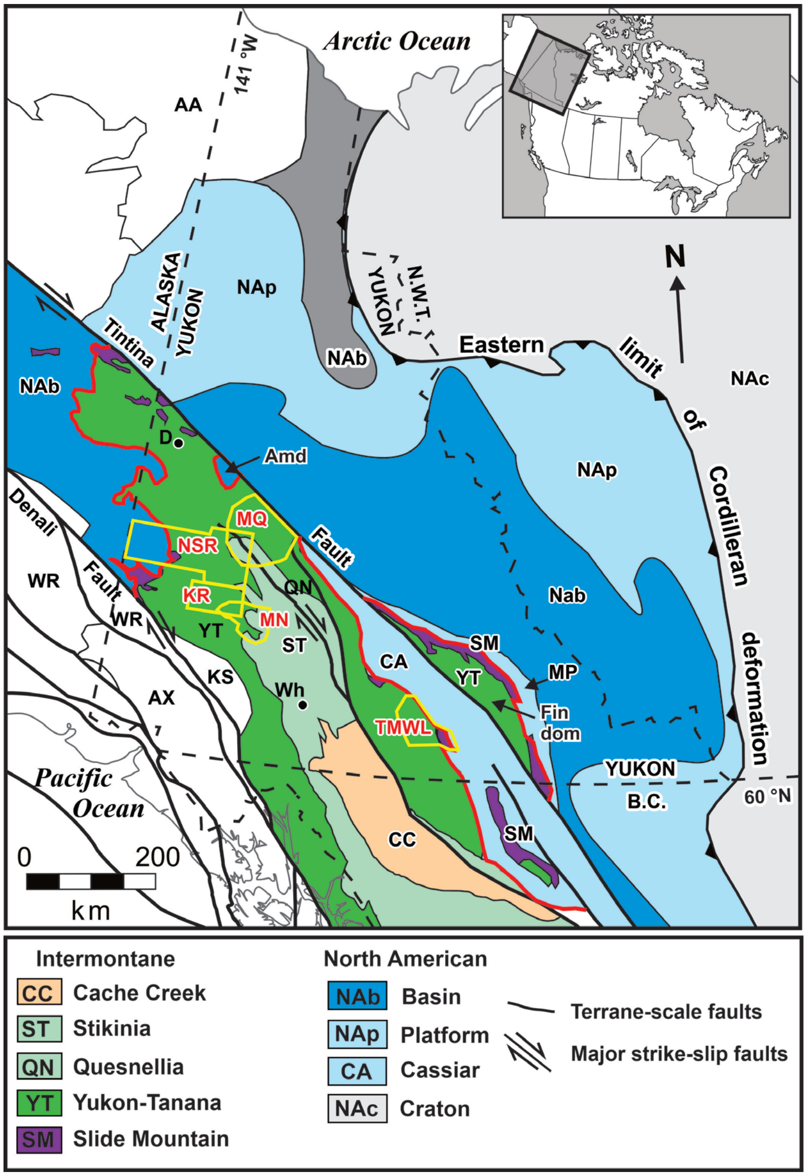

Figure 1. Simplified terrane map of the northern Canadian Cordillera (*modified from* Staples et al., 2016 and Colpron and Nelson, 2011), showing footprints of the McQuesten (MQ), northern Stevenson Ridge (NSR), Klaza River (KR), Mount Nansen-Nisling River (MN), and Thirtymile-Wolf Lake (TMWL) map areas outlined by yellow. Communities for reference: Dawson (D) and Whitehorse (Wh). The structure that bounds Yukon-Tanana and Slide Mountain terranes from North American rocks is outlined in red. Terrane abbreviations: Alexander (AX), Cassiar (CA), Cache Creek (CC), Kluane Schist (KS), McEvoy platform (MP), North American basinal strata (NAb), North American platformal strata (NAp), cratonic North America (NAc), Quesnellia (QN), Slide Mountain (SM), Stikinia (ST), Yukon-Tanana (YT), Wrangellia (WR). Inset shows location within North America. Amd = Australia Mountain domain, Fin dom = Finlayson domain, AA = Arctic Alaska

peraluminous augen and biotite orthogneiss (Dusel-Bacon et al., 2006, 2017; Dusel-Bacon and Williams, 2009). Siliciclastic rocks have Archean to Paleoproterozoic detrital zircon populations, characteristic of Laurentian provenance (Dusel-Bacon et al., 2017).

White River assemblage

The White River assemblage is exposed in the White River domain in western Yukon (Fig. 2) and has been correlated with the Lake George assemblage to the west in Alaska (Murphy et al., 2009; Ryan et al., 2014). The White River assemblage includes rocks ranging from pre-Late Devonian to Triassic (previously “Windy-McKinley” terrane; Murphy et al., 2008, 2009) and is intruded by the middle Cretaceous Whitehorse plutonic suite (Fig. 2; Ryan et al., 2013b, 2014). The White River assemblage comprises the Scottie Creek formation, the Mount Baker intrusive suite, the White River complex, and the Snag Creek gabbro suite (Ryan et al., 2013b). The White River assemblage is characterized by shallowly dipping tectonometamorphic layering; shallowly dipping, tabular intrusive sheets of the Late Triassic Snag Creek suite gabbro and diabase (ca. 230–228 Ma: Murphy et al., 2009). The state of deformation and metamorphism of the Snag Creek suite varies significantly, ranging from highly strained amphibolite facies to macroscopically undeformed subgreenschist facies. The Snag Creek suite has been correlated with gabbroic intrusions in Early Devonian schist in the Delta mineral belt of eastern Alaska (Dashevsky et al., 2003; Dusel-Bacon et al., 2006) and the Galena suite gabbro in the Laurentian margin of the McQuesten and Mayo areas of Yukon (Murphy, 1997).

Contents

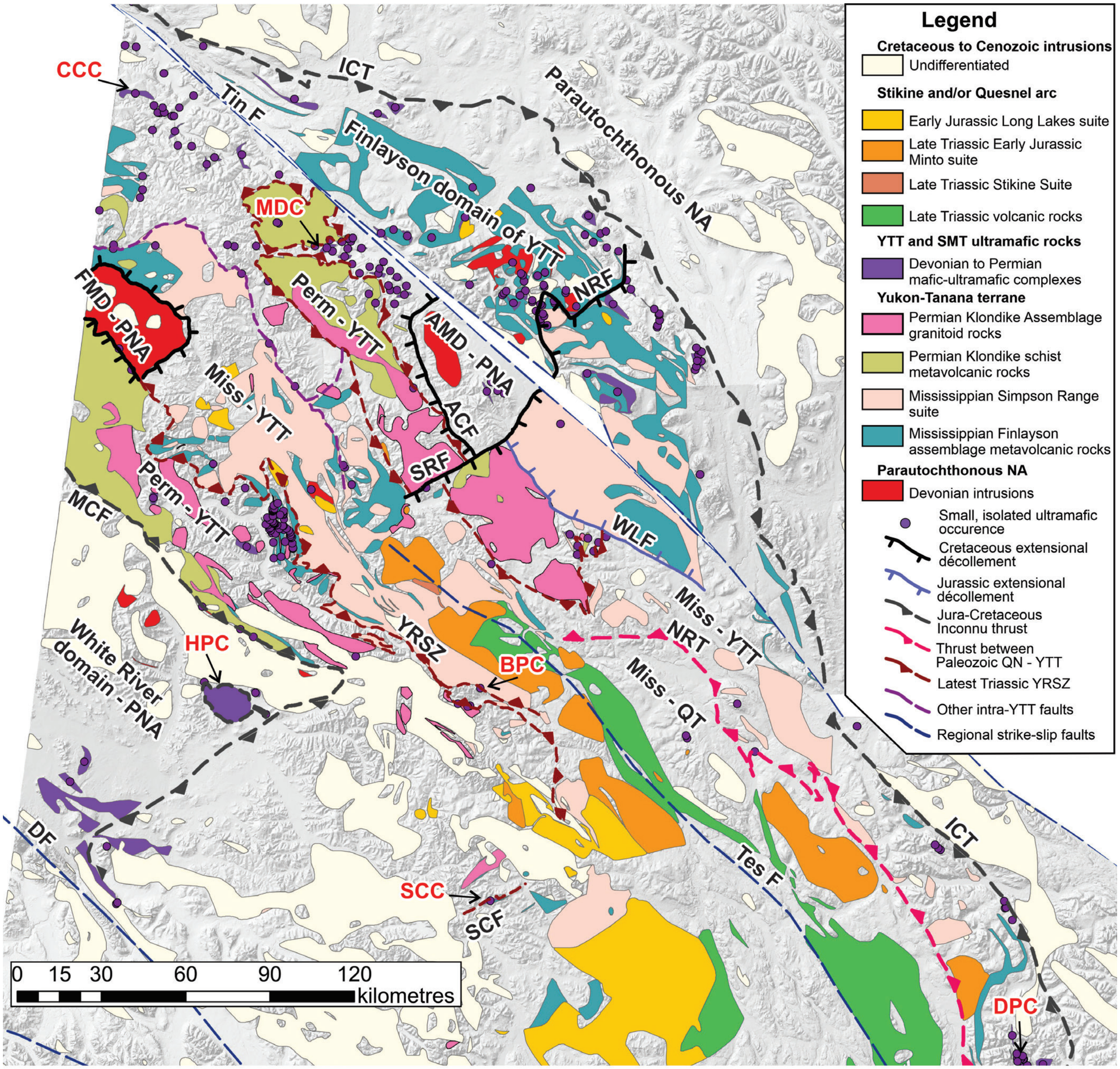

Figure 2. Structural architecture and domain map of Yukon-Tanana terrane (YTT) and its relationship with parautochthonous North American (PNA). Units are shown with approximated restoration of 450 km of dextral offset along the Tintina Fault (Tin F), such that the Finlayson Lake domain of Yukon-Tanana terrane restores immediately east of Yukon-Tanana terrane exposed in the Stewart River and McQueston map areas. Early Paleozoic to Middle Mesozoic magmatic suites that define the structural architecture are highlighted on a background of undifferentiated Yukon-Tanana terrane basement and other rocks. The Inconnu thrust (ICT) and its equivalent structure on the west side of Yukon-Tanana terrane, the Moose Creek fault (MCF), bound Yukon-Tanana terrane from parautochthonous North American margin rocks. The internal composite architecture of Yukon-Tanana terrane is highlighted with the Yukon River shear zone (YRSZ). The complete trace of the Yukon River shear zone shown here is speculative, and marked in part by tectonic lozenges of ultramafic rocks. The Buffalo Pitts complex (BPC), an orogenic peridotite, lies along the Yukon River shear zone. The Schist Creek complex (SCC) is also interpreted to be an orogenic peridotite, and lies along the Schist Creek Fault (SCF). Other abbreviations: AMD = Australia Mountain domain, DF = Denali Fault, Tes F = Teslin Fault, SRF = Stewart River fault, NRF = North River fault, WLF = Willow Lake fault, ACF = Australia Creek fault, QN = Quesnellia, FMD = Fiftymile domain, NRT = Needlerock Thrust, CCC = Clinton Creek complex, MDC = Midnight Dome complex, HPC = Harzburgite Peak complex, DPC = Dunite Peak complex, Miss = Mississippian.

Scottie Creek formation

The Scottie Creek formation (Murphy et al., 2009) comprises psammitic muscovite-biotite schist, quartzite, and pebble conglomerate (Fig. 3a; Ryan et al., 2014). Weather-resistant quartzite is typically exposed on ridges, whereas psammitic schist is interpreted to underlie much of the low-lying areas. In the northwestern part of the White River assemblage, the Scottie Creek formation appears to be migmatized, exhibiting contorted layers of mica-rich melanosome and garnet-bearing quartzofeldspathic leucosome. Two quartzite samples yielded youngest detrital zircon grains of ca. 376 Ma and 368 Ma (N. Joyce, unpub. data, 2019), and a quartzofeldspathic schist within the migmatite domain yielded a probable detrital zircon age of ca. 365 Ma (N. Joyce, unpub. data, 2019), and the present authors interpret the rock to have an epiclastic protolith. These ages suggest it was wholly or in part contemporaneous with the White River complex.

White River complex

The White River complex comprises variably strained metavolcanic rocks and minor carbonaceous schist that have been metamorphosed at greenschist to amphibolite facies (Ryan et al., 2014). They include amygdaloidal andesitic to basaltic flows, quartz and feldspar porphyry (Fig. 3b), and rhyolite. A rhyolite sample yielded a U/Pb zircon crystallization age of ca. 368 Ma (N. Joyce, unpub. data, 2019). Murphy et al. (2009) reported an age of ca. 363 ± 3 Ma for a sample of crystal-lithic tuff of the White River complex.

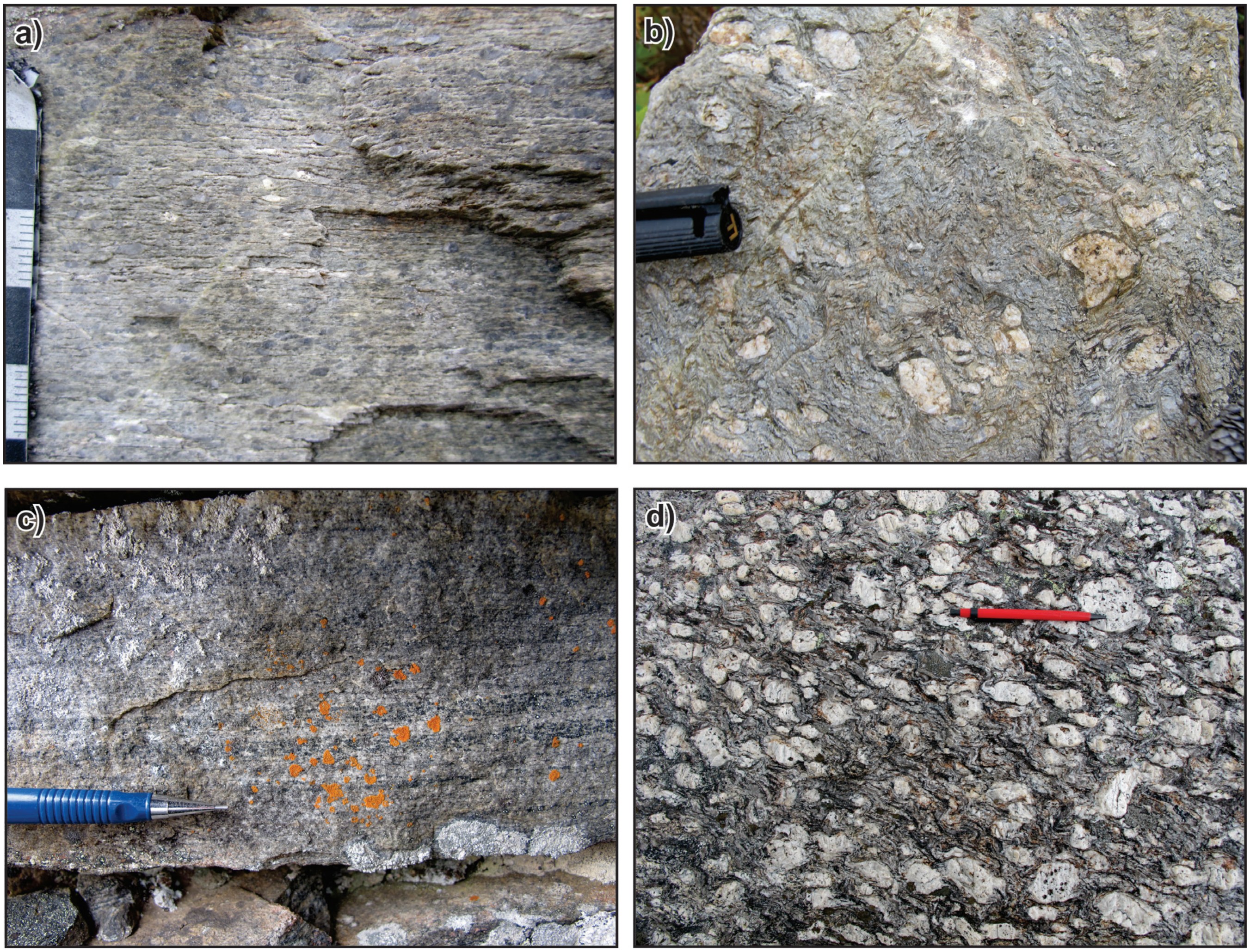

Figure 3. Field outcrop photographs of typical rock types of parautochthonous North American margin in western Yukon. **a)** Possible chert-pebble conglomerate from the Scottie Creek formation of the White River domain; scale card in centimetres. Photograph by A. Zagorevski. NRCan photo 2019-760. **b)** Quartz-feldspar hypabyssal porphyritic rhyolite of the White River complex; section of pen cap is 3 cm. Photograph by J.J. Ryan. NRCan photo 2019-761. **c)** Highly strained tonalite orthogneiss of the Mount Baker suite with orange lichen; section of pencil shown is 6 cm. Photograph by J.J. Ryan. NRCan photo 2019-762. **d)** Late Devonian augen granite of the Mount Burnham orthogneiss, considered part of parautochthonous North American margin; pencil is 15 cm. Photograph by J.J. Ryan. NRCan photo 2019-763.

These ages are within error of the Scottie Creek formation youngest detrital zircon. The White River complex ages also overlap ages of metavolcanic units associated with the Laurentian margin in the Big Delta district of eastern Alaska (Dashevsky et al., 2003; Dusel-Bacon et al., 2006) and the Earn Group in the Anvil and Earn lakes area (Cobbett, 2015, 2016) east of the Inconnu thrust (Yukon Geological Survey, 2019).

Mount Baker suite

The Mount Baker suite (Ryan et al., 2013b, 2014) comprises orthogneiss (Fig. 3c) derived from interlayered monzogranite, granodiorite, tonalite, diorite, and gabbro. Its well defined foliation and common dynamic recrystallization textures indicate a high degree of strain. The contact between the Mount Baker suite and the Scottie Creek formation is not exposed. The U/Pb zircon dating yielded an age of ca. 369 Ma (N. Joyce, unpub. data, 2019). This age is similar to those reported from the Butte assemblage and Totatlanika Schist of eastern Alaska parautochthonous North American margin (Dusel-Bacon et al., 2006, 2017).

Australia Mountain domain

The Australia Mountain domain (Fig. 2; Staples et al., 2013, 2016) was previously included in Yukon-Tanana terrane (e.g. Colpron et al., 2006a). The domain is largely dominated by siliciclastic rocks that record medium- to high-grade metamorphism (garnet-kyanite-sillimanite assemblage), and is cored by a large body of Devono-Mississippian Mount Burnham orthogneiss derived from porphyritic granite (Fig. 3d; Gordey and Ryan, 2005; Ruks et al., 2006). The U-Pb zircon dates for this augen granite are ca. 363.8 ± 1.5 Ma (Mortensen, 1990) and 360.4 ± 2.2 Ma (N. Joyce, unpub. data, 2019). An undeformed aplite dyke that cuts the foliation in the Mount Burnham orthogneiss yielded a U-Pb zircon crystallization age of 118.7 ± 1 Ma (N. Joyce, unpub. data, 2019). Pressure estimates of Staples et al. (2013) indicate that the Australia Mountain domain was at 9 kbar at ca. 118 Ma, and exhumed to 5 kbar to 4 kbar by 112 Ma along the Australia Creek fault. The exposure of the mid-Cretaceous (Albian) Indian River Formation (Lowey and Hills, 1988), and ca. 110–107 Ma ash beds (Yukon Geological Survey, 2019), in the hanging wall of the Australia Creek fault, requires approximately 27 km of vertical displacement on the Australia Creek fault between 118 Ma and 107 Ma (Staples et al., 2013). This contrasts with the similar rocks of the Yukon-Tanana terrane, which were already exhumed to argon closure temperature of hornblende, biotite, and muscovite by the Early Jurassic (Joyce et al., 2015). The different exhumation history of the Australia Mountain domain, combined with the lack of magmatic ages that are characteristic of Yukon-Tanana terrane, suggest that the Australia Mountain domain represents an exhumed portion of parautochthonous North American margin that structurally underlies Yukon-Tanana terrane (e.g. Dusel-Bacon et al., 2002; Staples et al., 2013, 2016; Ryan et al., 2017).

YUKON-TANANA TERRANE

The Yukon-Tanana terrane is characterized by the Snowcap assemblage siliciclastic-dominated basement (Colpron et al., 2006a, b; Piercey and Colpron, 2009) that was overprinted by Late Devonian to Jurassic magmatism, metamorphism, and deformation (Piercey et al., 2006; Nelson et al., 2006). Primary tectonostratigraphic relationships are difficult to establish due to complex deformation and typically amphibolite-facies metamorphism (e.g. Tempelman-Kluit, 1979; Mortensen, 1992; Berman et al., 2007; Staples et al., 2016). The Yukon-Tanana terrane comprises four tectonometamorphic assemblages (*see* Fig. 6 of Colpron et al., 2006a). The basal part of the Snowcap assemblage basement is overlain by three unconformity-bounded volcanic and volcaniclastic successions and intruded by consanguineous continental arc plutons (Piercey et al., 2006) of the Upper Devonian to Lower Mississippian Finlayson assemblage, the mid-Mississippian to Lower Permian Klinkit assemblage, and the Middle to Upper Permian Klondike assemblage (Colpron et al., 2006a; Piercey et al., 2006).

Snowcap assemblage

The Snowcap assemblage basement of Yukon-Tanana terrane has been interpreted as a rifted fragment of the western continental margin of Laurentia (Colpron et al., 2006a, b, 2007; Nelson et al., 2006, 2013). No crystalline basement portion of Yukon-Tanana terrane has yet been identified below the Snowcap assemblage, and direct correlations with stratigraphy of the craton are yet to be made. Detrital zircon geochronology age distributions, geochemical and Nd-Hf isotopic compositions, and other geological relationships indicate that northwestern Laurentia is the most likely source of the Snowcap assemblage siliciclastic rocks (Gehrels et al., 1991; Creaser et al., 1997, 1999; Patchett and Gehrels, 1998; Nelson et al., 2006; Nelson and Gehrels, 2007; Piercey and Colpron, 2009; N.R. Cleven, J.J. Ryan, D. Kellett, W. McClelland, A. Zagorevski, N. Joyce, J. Crowley, and A. Parsons, unpub. manuscript, 2021).

The Snowcap assemblage has very few direct age constraints, but is older than crosscutting Late Devonian to Early Mississippian plutons (Colpron et al., 2006b; Piercey and Colpron, 2009). In west-central Yukon, the Snowcap assemblage is composed mainly of quartzite, micaceous quartzite, psammitic quartz-muscovite-biotite (±garnet) schist, marble, and grey carbonaceous schist. Quartzite is generally fine grained, banded to massive, grey to white, and locally dark grey (Fig. 4a). One of the quartzite samples of this study from the northern Stevenson Ridge area yielded a

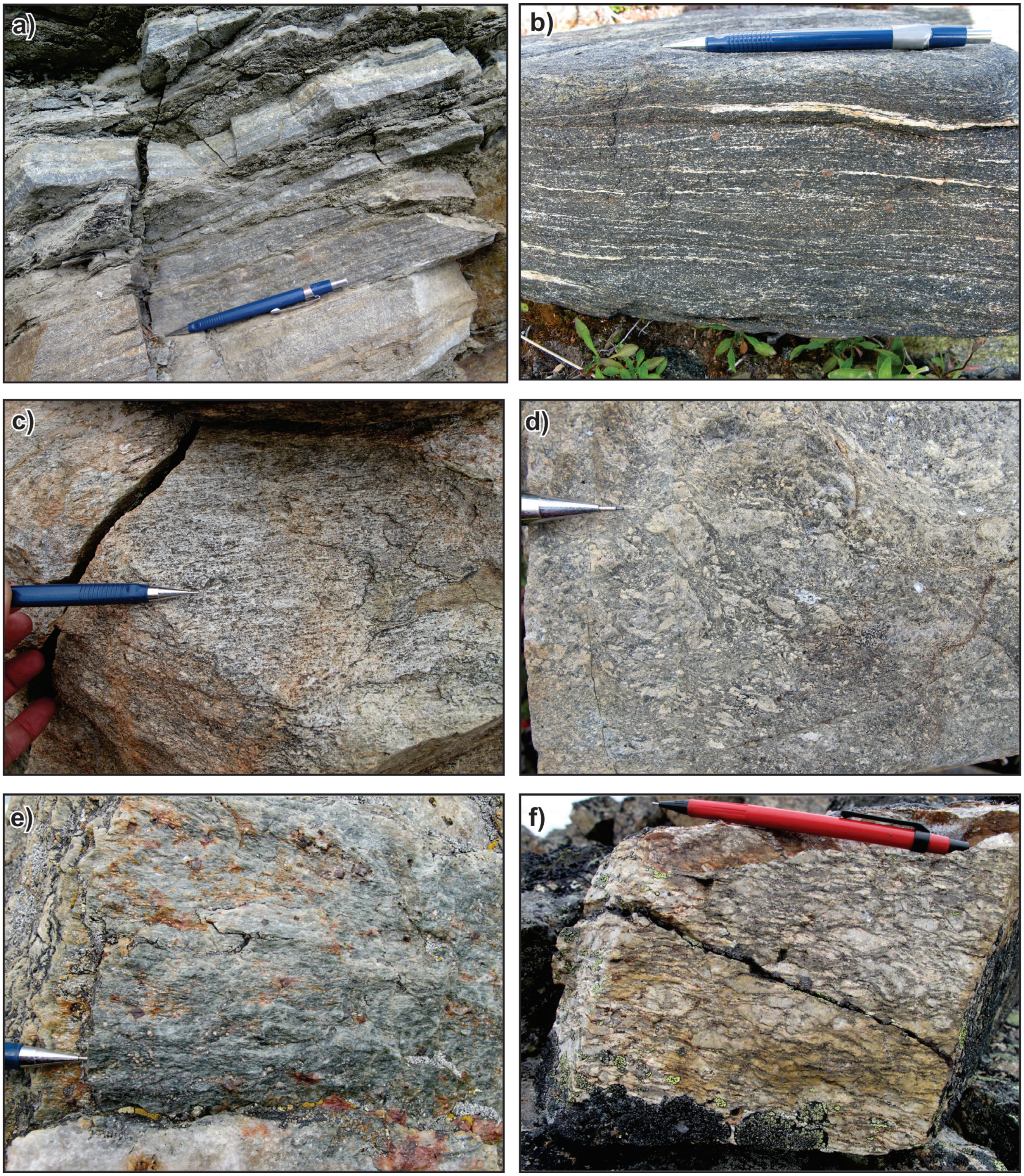

Figure 4. Field outcrop photographs of typical rock types in Yukon-Tanana terrane in western Yukon. **a)** High-strain quartzite of the Snowcap assemblage; pencil is 15 cm. NRCan photo 2019-764. **b)** Finlayson assemblage garnet-hornblende-plagioclase±quartz amphibolite interpreted to have a mafic volcanic protolith; pencil is 15 cm. NRCan photo 2019-765. **c)** Simpson Range suite foliated and lineated hornblende-biotite and biotite granodiorite; portion of pencil showing is 7 cm. NRCan photo 2019-766. **d)** Unusually well preserved felsic lapilli tuff (1–10 cm fragments) of Permian Klondike schist; pencil tip is 2 cm. NRCan photo 2019-767. **e)** Permian Klondike schist, chlorite-sericite phyllonite exhibiting quartz veins, and characteristic relict pyrite porphyroblasts; pencil tip is 3 cm. NRCan photo 2019-768. **f)** Typical K-feldspar porphyroclastic augen granite of Permian Sulphur Creek suite (Klondike assemblage); pencil is 15 cm. NRCan photo 2019-769. All photographs by J.J. Ryan.

youngest detrital zircon age of ca. 370 Ma (N. Joyce, unpub. data, 2020). Garnet-bearing pelitic schist is common, but not extensive, and horizons of conglomerate with pebble-sized clasts of quartzite and mudstone occur very locally within the psammitic schist. The Snowcap assemblage is variably calcareous, with centimetre- to decametre-thick marble or calc-silicate horizons occurring sporadically throughout. At the type locality of Snowcap Mountain, Piercey and Colpron (2009) described thin, possibly volcanic, amphibolite horizons associated with carbonate rocks. In regions studied herein, massive amphibolite and garnet amphibolite layers that are associated with the Snowcap assemblage are interpreted as metamorphosed mafic sills and dykes of unknown age.

Devono-Mississippian tectonostratigraphy

Finlayson assemblage

The Finlayson assemblage is generally interpreted as a metamorphosed Late Devonian to Early Mississippian continental arc and back-arc volcano-sedimentary succession that unconformably overlies the Snowcap assemblage (Colpron et al., 2006a, 2007). Internal stratigraphy within the Finlayson assemblage is highly variable. In the Finlayson Lake district, it comprises bimodal magmatic rocks of arc and back-arc affinity which host volcanic-associated massive-sulphide deposits (Murphy et al., 2006, Piercey et al., 2006). In west-central Yukon, the Finlayson assemblage comprises extensive amphibolite, with less consistent stratigraphy than the Finlayson Lake district, and can exhibit hornblende-plagioclase±epidote or garnet-hornblende-plagioclase±quartz mineral assemblages (Fig. 4b). Local relict volcanic features suggest a volcanic protolith. Presence of massive amphibolite layers suggests that some of the mafic rocks were emplaced as flows or sills. Locally, amphibolite is interlayered with marble and siliciclastic metasedimentary rocks of the upper Snowcap assemblage, though at some localities this contact is definitively structural. Finlayson assemblage felsic rocks are sparse in west-central Yukon, but possible felsic metavolcanic rocks yielded a 347.6 ± 3.5 Ma U-Pb zircon crystallization age (Ryan et al., 2016; Joyce et al., 2020).

In the Finlayson Lake area, the carbonaceous sedimentary rocks are included in the Wolverine Lake Group, and are interstratified with early Mississippian volcanic rocks and associated massive-sulphide deposits (Murphy et al., 2006). In northwest Yukon-Tanana terrane this carbonaceous succession is known as the Nasina assemblage (Mortensen, 1992; Dusel-Bacon et al., 2006; Allan et al., 2013) and the Stevenson Ridge schist (Ryan et al., 2014, 2018a). In southern Yukon it is included in the Swift River formation (Roots et al., 2006). These carbonaceous rocks are typically mapped as grey to black, carbonaceous quartzite, psammite, and phyllite, however, it is probable that some units are derived from carbonaceous shale and chert. Finlayson assemblage carbonaceous rocks contains variable amounts of marble, from almost completely lacking in the Stevenson Ridge area to being prominent in the Klondike region (Yukon Geological Survey, 2019). Finlayson assemblage carbonaceous siliciclastic rocks are considered to represent anoxic back-arc basin deposits to the Finlayson arc (Colpron et al., 2006a; Yukon Geological Survey, 2019).

Simpson Range suite

The Late Devonian to Early Mississippian Simpson Range suite is defined in the Finlayson Lake area of southeast Yukon (Mortensen, 1992; Murphy et al., 2006). Simpson Range suite granitoid rocks are abundant in the west-central Yukon region covered under this project. They comprise variably foliated to gneissic hornblende-biotite and biotite granodiorite (Fig. 4c), with minor monzogranite, diorite, gabbro, and amphibolite. They yield crystallization ages between 363 Ma and 340 Ma (e.g. Knight et al., 2013; Joyce et al., 2020). The Simpson Range suite locally contains rafts and xenoliths of metavolcanic rocks that are interpreted to form part of the Finlayson assemblage. Regionally, the Simpson Range suite commonly contains abundant inherited zircon (Murphy et al., 2006; Piercey et al., 2006) and has a variable, juvenile to highly evolved isotopic signature (Piercey et al., 2006). Inherited zircon and evolved isotopic signatures suggest that parts of the Simpson Range suite were derived from or intruded into the Yukon-Tanana terrane basement.

In the northern Stevenson Ridge area, the Simpson Range suite is juxtaposed with the Snowcap assemblage along the Yukon River shear zone (Tempelman-Kluit, 1974; Ryan et al., 2014; Parsons et al., 2018). The Simpson Range suite plutons in this area yielded three U-Pb ages between ca. 347 to 344 Ma, do not have inherited zircon crystals, and are intruded by the Late Triassic Stikine and Pyroxene Mountain plutonic suites (Ryan et al., 2014; Parsons et al., 2018; N. Joyce, unpub. data, 2020). This suggests that some components of this suite formed on a more juvenile basement than is typical for Yukon-Tanana terrane, and may actually be correlative to something more akin to the Mississippian Takhini-Stikine assemblage of Stikinia (e.g. Hart, 1997; Logan et al., 2000).

Permian tectonostratigraphy of the Klondike assemblage

The Middle to Late Permian (269–253 Ma) Klondike assemblage forms the youngest magmatic constituent of the Yukon-Tanana terrane. It comprises metavolcanic and epiclastic rocks of the Klondike schist and metaplutonic rocks of the Sulphur Creek suite (Mortensen, 1992; Nelson et al., 2006). Volumetrically significant exposures of the Klondike assemblage are restricted to two subparallel belts in west-central Yukon and eastern Alaska (Fig. 2; e.g. Gordey and

Ryan, 2005; Beranek and Mortensen, 2011; Ryan et al., 2013a, b, 2014). Volumetrically minor dykes and plugs related to the Klondike assemblage occur through much of Yukon-Tanana terrane (Yukon Geological Survey, 2019). The GEM mapping greatly expanded known occurrences of the Klondike assemblage, particularly in the McQuesten (Ryan et al., 2010; Knight et al., 2013), northern Stevenson Ridge (Ryan et al., 2013a, b), and Klaza River areas (Ryan et al., 2018a; Joyce et al., in press).

Klondike schist

The Klondike schist comprises variably deformed, greenschist-facies hypabyssal, volcanic, and sedimentary rocks. Locally, quartz- and feldspar-porphyritic felsic volcanic and volcaniclastic rocks are well preserved (Fig. 4d), however, much of the Klondike schist comprises strongly deformed sericite, chlorite, and quartz-feldspar augen schist and phyllonite derived from felsic to intermediate volcanic rocks. Mafic rocks are rare (e.g. Colpron and Ryan, 2010). The Klondike schist commonly has pitted weathering surfaces produced by weathering of pyrite porphyroblasts (Fig. 4e). Two samples of lapilli tuff from the northern Stevenson Ridge area yielded ca. 259 to 256 Ma crystallization ages (N. Joyce, unpub. data, 2020).

Sulphur Creek suite

The Sulphur Creek suite comprises variably deformed K-feldspar and quartz porphyritic to equigranular syenogranite to granodiorite (e.g. Mortensen, 1992; Gordey and Ryan, 2005). Strain within the suite varies significantly from relatively undeformed, to greenschist-facies porphyroclastic phyllonite, to amphibolite-facies augen orthogneiss (Fig. 4f) in porphyritic protoliths. In many locations across west-central Yukon, the Sulphur Creek suite demonstrably intrudes the Snowcap assemblage and both are metamorphosed at amphibolite facies. In the northern Stevenson Ridge area, the Sulphur Creek suite is deformed and metamorphosed to greenschist-facies quartz-sericite-chlorite phyllonite. These largely obliterated primary plutonic textures make these granitoid rocks indistinguishable from the Klondike schist metavolcanic rocks. Sulphur Creek granitoid rocks from west-central Yukon yielded U-Pb zircon ages ca. 262 to 254 Ma (Mortensen, 1992; Ruks et al., 2006; Parsons et al., 2018; Joyce et al., in press; N. Joyce, unpub. data, 2020).

Ultramafic complexes internal to the Yukon-Tanana terrane

As is discussed in 'Slide Mountain terrane ophiolitic rocks' section, numerous mafic-ultramafic complexes located between Yukon-Tanana terrane and parautochthonous North American margin are probably related to the Slide Mountain terrane, however, there are also numerous complexes throughout Yukon-Tanana terrane that lack any petrogenetic constraints. Many of these complexes are strongly deformed, altered, and metamorphosed to serpentine-, amphibole-, and chlorite-rich lithologies, making protoliths difficult to characterize. Often, these bodies have been mapped as tabular or sheet-like, and are commonly interpreted as representing metamorphosed sills or dykes. The emplacement history of these rocks, whether they may be ophiolites, orogenic peridotites, or magmatic intrusions, may be possible with further targeted research. Two of these mafic-ultramafic complexes are described here; their relationship to possible crustal-scale structures is discussed in the section devoted to 'Nature of crustal structures related to Yukon-Tanana terrane tectonic evolution'.

Buffalo Pitts complex

The Buffalo Pitts mafic-ultramafic complex comprises a small body (about 200 m by 500 m) of harzburgite, troctolite, banded pyroxenite, skarn, and garnet amphibolite that were structurally imbricated with the metasedimentary rocks of the Snowcap assemblage north of Sonora Gulch (Fig. 2, 5; Canil et al., 2003; Ryan et al., 2013b). The peridotite age is constrained by leucogabbro within it that dated at ca. 262 Ma (Johnston et al., 2007) and ca. 267 Ma (N. Joyce, unpub. data, 2020). The peridotite preserved evidence of rapid decompression from spinel to plagioclase stability fields during exhumation, suggesting that it originated as continental lithospheric mantle that was exhumed during Permian continental rifting (Canil et al., 2003; Johnston et al., 2007). In such settings, peridotites are exhumed along transcrustal faults; however, these structures can be reactivated or overprinted by younger deformation. Buffalo Pitts peridotite lies along a fault which is outlined by a distinct lineament in high-resolution aeromagnetic data (Ryan et al., 2013b), and appears to be a fault splay in close proximity to the more regionally extensive Yukon River fault (Ryan et al., 2014; Coleman, 2017; Parsons et al., 2018).

Schist Creek complex

The Schist Creek mafic-ultramafic complex is an east-northeast-trending isolated sliver (1 km by 7 km) of serpentinized alpine peridotite located in the Mount Nansen–Nisling River area (Fig. 2, 6), within Yukon-Tanana terrane (Ryan et al., 2016, 2018a). Mapping, petrography, and geochemistry indicate that the largely serpentinite body has a predominantly harzburgitic protolith, indicated by high-temperature, deformed orthopyroxene porphyroclasts and aligned olivine, suggesting that it originated as lithospheric mantle (Dubman, 2016). Serpentinite is intruded by plagioclase porphyritic metagabbro dykes (Ryan et al., 2016) that yield late Permian (ca. 265 Ma to 263 Ma) ages (W. McClelland, unpub. data, 2016). Nearby minor lenses

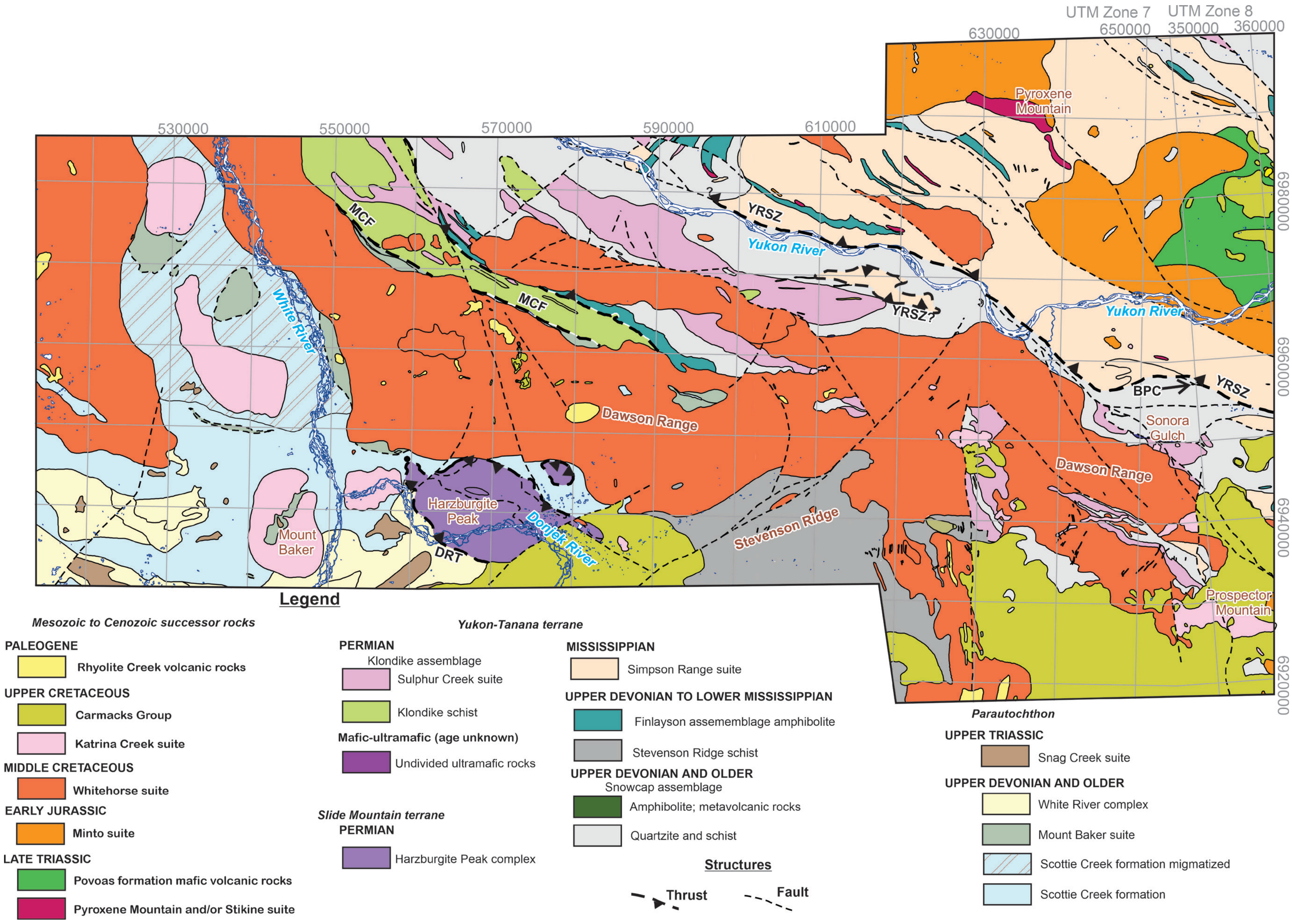

Figure 5. Geology of the northern Stevenson Ridge area (*after* Ryan et al., 2013a, b). Faults bounding the main structural panels are indicated with a heavy line thickness. Yukon River shear zone (YRSZ), Moose Creek fault (MCF), Donjek River thrust (DRT). BPC = Buffalo Pitts complex

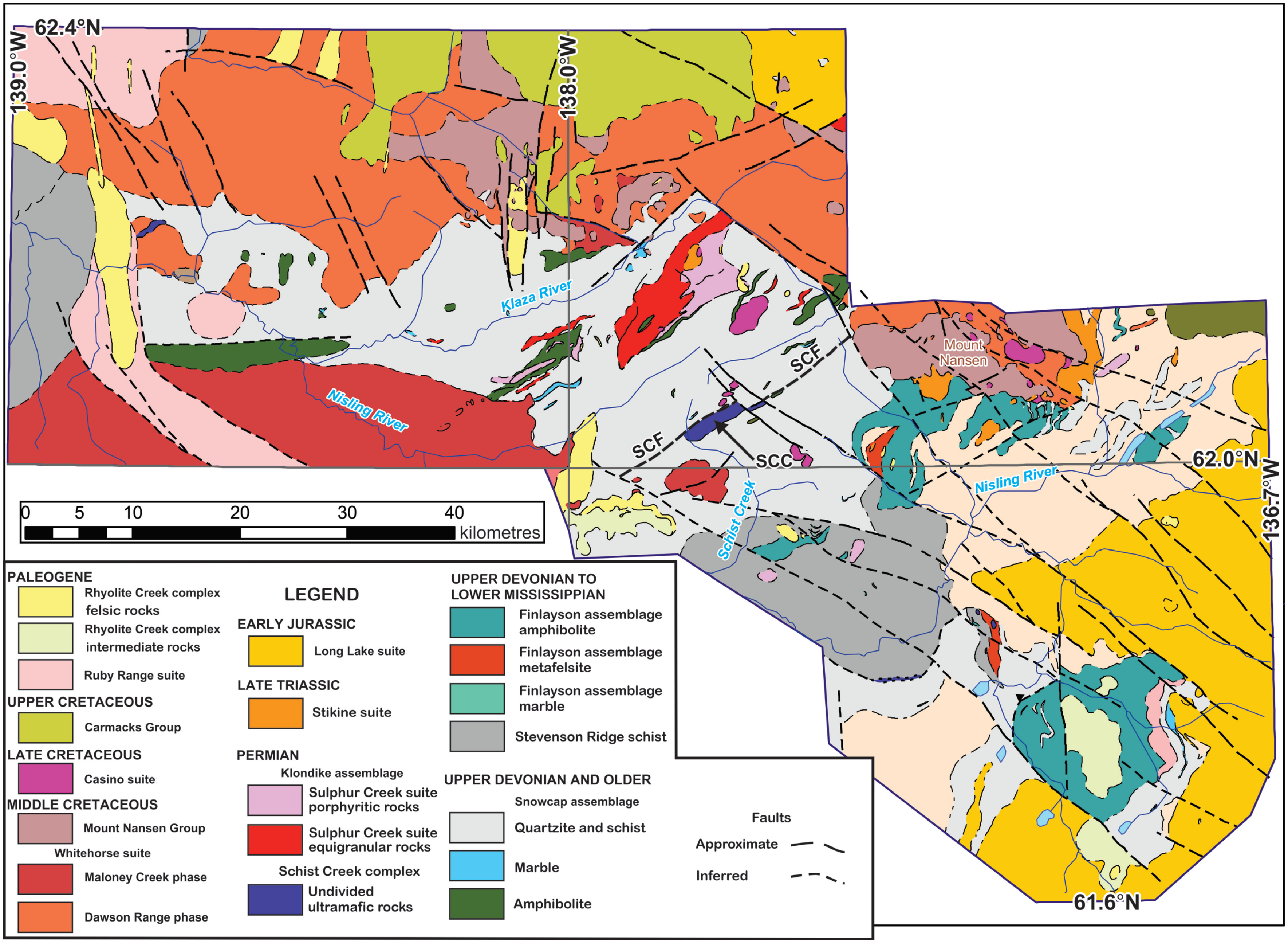

Figure 6. Geology of the combined Klaza River area (west side; *after* Ryan et al., 2018a) and Mount Nansen-Nisling River area (east side; *after* Ryan et al., 2016). The Schist Creek fault (SCF) and the Schist Creek complex (SCC) bound a domain of Permian igneous rocks to the northwest from a domain with Mississippian igneous rocks to the southeast.

(10 m to 100 m wide) of serpentinite, talc-tremolite schist, and listwaenite may also be related to the Schist Creek complex.

Regional overview of Yukon-Tanana terrane and parautochthonous North American margin detrital zircon geochronology

Numerous samples of siliciclastic rocks were collected for detrital zircon U-Pb geochronology during the course of GEM-2 fieldwork. Samples were analyzed by Sensitive High-Resolution Ion Micro Probe (SHRIMP) techniques at GSC laboratory facilities in Ottawa and by laser-ablation inductively coupled plasma mass spectrometry (LA-ICPMS) techniques at both Boise State University and the Arizona LaserChron centre at Arizona State University. Sample and methodology details are provided in an unpublished report by N.R. Cleven and colleagues (N.R. Cleven, J.J. Ryan, D. Kellett, W. McClelland, A. Zagorevski, N. Joyce, J. Crowley, and A. Parsons, unpub. manuscript, 2021).

Detrital zircon geochronology is a very effective tool for deciphering regional tectonomagmatic histories. Detrital zircon age distributions can illustrate past magmatic periods, periods of tectonism, and recycling of sediments by sampling broad regions of zircon-bearing source rocks (Moecher and Samson, 2006; Hawkesworth et al., 2009). Detrital zircon crystals can also preserve evidence of units that are no longer exposed (structural or stratigraphic burial) or have been entirely eroded.

The GEM-2 detrital zircon sample data set has a wide spatial and temporal extent. As such, it provides a comprehensive view of Paleozoic magmatic periods responsible for Cordilleran crustal evolution. Composite age distributions for Late Devonian to Permian detrital zircon samples exhibit two dominant age peaks at ca. 353 Ma and 266 Ma, with a subsidiary peak at ca. 331 Ma (Fig. 7). These age peaks match well with known ages of magmatism in the Yukon-Tanana terrane (e.g. Nelson et al., 2006). The minor, widely distributed age component with a peak age ca. 431 Ma does not match known ages of magmatism in the Yukon-Tanana terrane, but has been described in locally derived sediment in the parautochthonous North American margin strata in northern British Columbia (Gehrels and Pecha, 2014). The Paleoproterozoic and Archean signature within the Late Devonian to Permian samples is essentially indistinguishable from the underlying siliciclastic basement and suggests that the basement was ubiquitously recycled into younger strata.

These detrital geochronology data also help to constrain the potential source regions of the Yukon-Tanana terrane siliciclastic basement, and degree of its recycling into the overlying supracrustal sequences (e.g. Pecha et al., 2016). The Yukon-Tanana terrane siliciclastic basement (Snowcap assemblage, North River assemblage, and Dorsey Complex) is dominated by Paleoproterozoic and Archean ages (Fig. 7). It is a complex age distribution that comprises numerous age component peaks, with prominent peaks at ca. 1780 Ma, 1850 Ma, 2000 Ma, 2300 Ma, and 2650 Ma. These ages are consistent with a Laurentian provenance (*see* Piercey and Colpron, 2009). Trace amounts of Meso- and Neoproterozoic, and early Paleozoic, detrital zircon ages (Fig. 7) are not considered to be derived from a proximal cratonic source. Previous workers have proposed that Mesoproterozoic zircon may be derived from recycled Grenville clastic material that covered Laurentia (Gehrels and Pecha, 2014), such as Cambrian sediments of the Mackenzie Mountains (Hadlari

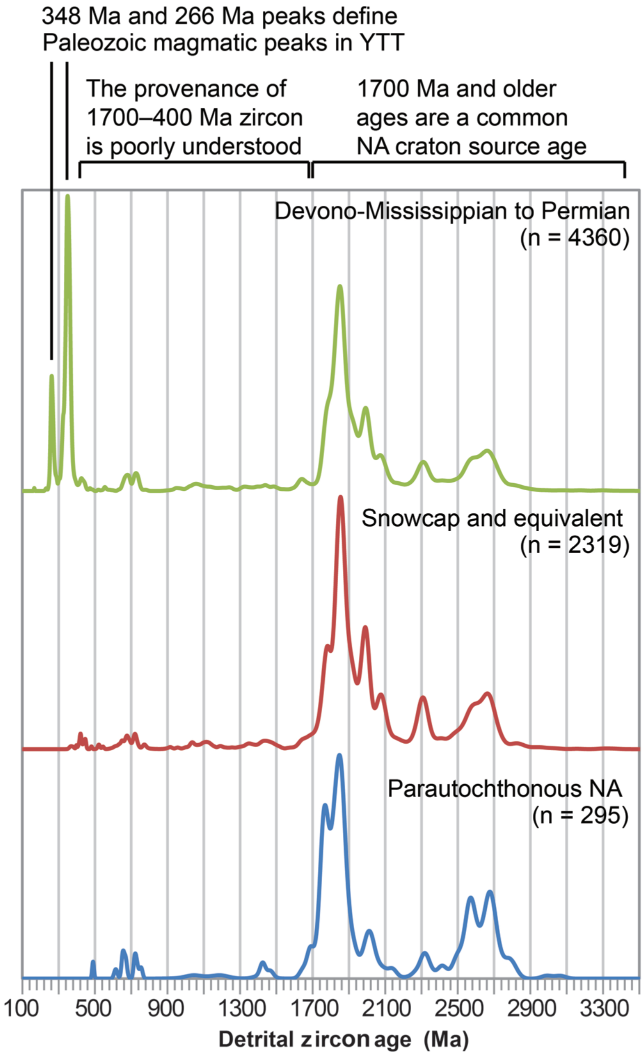

Figure 7. Normalized probability plot for zircon analyses from 34 samples of Yukon-Tanana terrane (YTT) and parautochthonous North American (NA) margin examined by Cleven and colleagues (N.R. Cleven, J.J. Ryan, D. Kellett, W. McClelland, A. Zagorevski, N. Joyce, J. Crowley, and A. Parsons, unpub. manuscript, 2021). The bottom graph is from parautochthonous samples. The middle graph is from Snowcap assemblage and equivalent samples. The upper graph is from Devono-Mississippian to Permian rocks. These all show general similarities in the pre-400 Ma age range of zircon samples.

et al., 2012). Neoproterozoic and Ordovician-Silurian populations are known in the Paleozoic Laurentian margin (e.g. Hadlari et al., 2012). These are generally thought to be exotic to Laurentia and derived from exotic terranes, proposed by some to be the Alexander terrane (Beranek et al., 2013; Gehrels and Pecha, 2014); however, a Cryogenian peak in the present study's data differs from Ediacaran populations reported for the Alexander terrane (Beranek et al., 2013).

Statistical comparison of detrital zircon age distributions (Vermeesch, 2013) of Laurentian margin (Gehrels and Pecha, 2014) and Yukon-Tanana terrane basement (N.R. Cleven, J.J. Ryan, D. Kellett, W. McClelland, A. Zagorevski, N. Joyce, J. Crowley, and A. Parsons, unpub. manuscript, 2021) permits detailed evaluation of the early Yukon-Tanana terrane history, including the widely accepted model of its rifting from Laurentia. Yukon-Tanana terrane basement samples are statistically most similar to Laurentian Neoproterozoic to Ordovician strata in southern British Columbia, and Ordovician to Devonian strata in northern British Columbia. Restoration of Cretaceous to Eocene fault displacements (~800 km; Gabrielse et al., 2006), places the Yukon-Tanana terrane at the same latitude as its statistically equivalent regions on the Laurentian margin. This suggests that the Middle to Late Devonian rift basin (Slide Mountain Ocean) that separated Yukon-Tanana terrane from Laurentia was very limited in width. This is strongly supported by similarities between Yukon-Tanana terrane basement age distributions and proximal samples of parautochthonous North American margin samples in the White River region.

SLIDE MOUNTAIN TERRANE OPHIOLITIC ROCKS

Oceanic assemblages of Devonian to Permian chert, argillite, mafic volcanic rocks, and mafic and/or ultramafic plutonic rocks of the Slide Mountain terrane in Yukon have been interpreted to represent vestiges of the Slide Mountain Ocean back-arc basin (e.g. Murphy et al., 2006) that developed following Yukon-Tanana terrane rifting from the western margin of North America (e.g. Mortensen, 1992; Nelson et al., 2013). Earlier studies proposed that west-dipping subduction of the Slide Mountain Ocean beneath the Yukon-Tanana terrane caused accretion of Yukon-Tanana terrane to the North American margin during the middle Permian (e.g. Mortensen, 1992; Beranek and Mortensen, 2011). Those models interpret Yukon-Tanana terrane as the arc (upper plate) and the Slide Mountain terrane as accreted remnants of the subducting (lower) plate (Nelson et al., 2006; Piercey et al., 2006); however, the present authors' more recent investigation of the Slide Mountain terrane indicates that Permian Slide Mountain terrane ophiolites were generated in a suprasubduction zone (upper plate) setting and were obducted onto Yukon-Tanana terrane (Parsons et al., 2019; van Staal et al., 2018). The previous tectonic framework cannot adequately explain the incorporation of ophiolitic rocks along such boundaries, as it requires either several coexisting subduction zones or re-evaluation of the tectonic setting of Middle Permian Yukon-Tanana terrane. A more consistent explanation of the structural arrangement of Slide Mountain terrane and Yukon-Tanana terrane rocks is that parts of Yukon-Tanana terrane subducted eastward beneath an intra-oceanic arc within the Slide Mountain Ocean (e.g. van Staal et al., 2018; Parsons et al., 2019). Importantly, this model requires subsequent collision and accretion between the Yukon-Tanana terrane and North American Craton to occur after the Permian (Parsons et al., 2018).

A large number and variety of mafic-ultramafic complexes occur sporadically within and between the pericratonic terranes (*see* Yukon Geological Survey, 2019), with a majority of the largest ones included in either the Slide Mountain terrane or Cache Creek terrane (Fig. 1), and these are reviewed in detail in the paper by Zagorevski et al. (this volume). A review by Parsons et al. (2019) of mafic-ultramafic rocks considered to be ophiolite fragments associated with Slide Mountain terrane, some within Yukon-Tanana terrane, demonstrated that the vast majority of them have Early to middle Permian gabbroic components with suprasubduction zone whole-rock geochemical compositions. Reviews by van Staal et al. (2018) and Zagorevski et al. (this volume) found that Slide Mountain terrane ophiolites formed in suprasubduction zone settings immediately prior to collisions and accretion. Still, there are mafic-ultramafic rocks suspected to be ophiolitic within Yukon-Tanana terrane as old as Mississippian in the Finlayson Lake district (Devine et al., 2006; Murphy et al., 2006) and in the St. Cyr Klippe near Quiet Lake (Petrie et al., 2015), the origins of which are unclear. This section highlights some ophiolitic rocks examined under the Cordillera project that are included in the Slide Mountain terrane, and have strong bearing on the location and nature of the boundary between Yukon-Tanana terrane and parautochthonous North American margin.

Ultramafic rocks along the Moose Creek fault

During mapping in the northern Stevenson Ridge area, Ryan et al. (2013a, b) delineated several lenses (tens of metres to about 1 km in thickness) of harzburgite, dunite, orthopyroxenite, serpentinite, talc-tremolite schist, and listwaenite along the boundary between Yukon-Tanana terrane (Fig. 5) and parautochthonous North American margin rocks of the White River assemblage. These ultramafic rocks are diverse in composition and are variably altered, but harzburgite occurrences have locally well developed foliations and lineations defined by orthopyroxene (Zagorevski et al., 2012). Such textures indicate high-temperature deformation consistent with shearing in the mantle. They lie along the Moose Creek fault (Ryan et al., 2014), which is masked by coincidence with the northern contact of the Dawson Range batholith (Ryan et al., 2013a). The ultramafic rocks have fairly high magnetic susceptibility; however, the contact areole of the Dawson Range batholith also contributes to the strong linear magnetic anomaly in the vicinity, making it difficult to predict the location of unexposed ultramafic rocks. The Moose Creek fault is apparently steeply dipping, and separates Yukon-Tanana terrane rocks from parautochthonous North American margin rocks, and the present authors therefore consider it as a fundamental regional structure.

Harzburgite Peak complex

The Harzburgite Peak mafic-ultramafic complex lies in the southwestern part of the northern Stevenson Ridge area (Fig. 5; Ryan et al., 2013a), and comprises multiple klippen of shallowly dipping, allochthonous sheets emplaced on deformed White River assemblage parautochthonous North American margin (Ryan et al., 2014). The Harzburgite Peak complex, described in detail in Canil and Johnston (2003), exhibits structural dismemberment whereby mantle peridotite is emplaced upon a unit of cumulate gabbro and diabase with early Permian trondhjemite sheets. This does not appear to be a typical Penrose-style ophiolite (Zagorevski et al., this volume).

The Harzburgite Peak complex klippen (Fig. 5) are likely situated near their primary suture, but any such structure is obscured by voluminous mid-Cretaceous intrusions and late Cretaceous volcanic successions. Whereas their petrogenesis is not well understood, the proximity of both Moose Creek and Harzburgite Peak ultramafic units to the Yukon-Tanana terrane–parautochthonous North American margin terrane boundary is consistent with their assignment to the Slide Mountain terrane.

Dunite Peak complex

The Dunite Peak complex (Fig. 2), with exceptional exposure and proximity to the Yukon-Tanana terrane and parautochthonous North American margin structural boundary, was studied under this project by Parsons et al. (2017a, b, 2019). It is a large ophiolitic klippen of mafic-ultramafic lithostratigraphy, emplaced on a marine metasedimentary succession that correlates to the Finlayson assemblage, in turn overlying a basal marble interpreted to be part of the Snowcap assemblage (Parsons et al., 2019). Its ultramafic section is structurally highest, with an underlying, well foliated crustal section of interlayered cumulate gabbro, layered gabbro, leucogabbro, and finer grained greenschist-facies hypabyssal and volcanic rocks. A gabbro with island-arc tholeiite chemistry yielded a crystallization age of 265 ± 4 Ma (Parsons et al., 2019). The current interpreted structural boundary with parautochthonous North American margin rocks is approximately 4 km east of the Dunite Peak klippe (Fig. 2), making it unclear how its basal fault ties structurally to the Inconnu thrust.

Clinton Creek and Midnight Dome complexes

The Clinton Creek and Midnight Dome complexes are the most northerly of the complexes investigated under the GEM Cordillera project (van Staal et al., 2018). Both complexes lie along strike in the Dawson area of western Yukon (Fig. 2), and comprise greenschist-facies serpentinized ultramafic rocks, with minor gabbroic intrusions that postdate serpentinization. Geochemical profiles of the gabbro units are characteristic of island-arc tholeiites (Zagorevski et al., this volume), and the Clinton Creek and Midnight Dome complexes yielded 265 ± 3 Ma and 264 ± 4 Ma crystallization ages, respectively (van Staal et al., 2018), similar to that of Dunite Peak, and typical of numerous mafic-ultramafic complexes affiliated with Slide Mountain terrane (Parsons et al., 2019). The Clinton Creek complex is structurally imbricated with late Triassic sedimentary rocks that likely unconformably overlie Yukon-Tanana terrane rocks in the area (Abbott, 1983; Beranek and Mortensen, 2011), and therefore reside on an ill-defined structure that is Late Triassic or younger. With restoration of 430 km of post-Late Cretaceous dextral displacement along the Tintina Fault, the trend of the Clinton Creek and Midnight Dome complexes do not strongly align with Slide Mountain terrane units on the eastern side of the Finlayson Lake assemblage (*see* Fig. 3 of Staples et al., 2016), however, the present authors still consider them to be part of the Slide Mountain terrane.

Wolf Lake complex

Recent mapping in the Wolf Lake complex in southern Yukon (Fig. 1) reveals poorly exposed, yet cohesive units of peridotite, gabbro, diabase, basalt, and volcaniclastic rocks exhibiting low-grade to retrograde metamorphism and little deformation (Cleven et al., 2018). Peridotite outcrops exhibit pyroxene crystals aligned into a foliation (*see* Fig. 6a of Cleven et al., 2018) and rounded porphyroclastic olivine crystals indicative of high-temperature deformation of mantle rocks. Supracrustal units that include volcaniclastic rocks structurally overlie mafic and ultramafic units; however, it is difficult to establish with certainty that all rocks are related to an ophiolitic assemblage. The Wolf Lake complex lies along the Yukon-Tanana terrane to parautochthonous North American margin boundary, which led to its inclusion in Slide Mountain terrane within current tectonic framework; however, work establishing the age and petrogenesis of the complex is ongoing.

NATURE OF CRUSTAL STRUCTURES RELATED TO YUKON-TANANA TERRANE TECTONIC EVOLUTION

There is still significant uncertainty with respect to the nature and location of boundaries within and between individual terranes, and the genetic setting of terrane components. For example, Zagorevski et al. (this volume) argue for distinct terranes within the Cache Creek terrane, which is generally accepted as being a singular terrane, whereas van Staal et al. (2018) and Parsons et al. (2019) present evidence for a Middle Permian arc–back-arc origin of the Slide Mountain terrane ophiolites. These studies indicate that the Cordilleran tectonic framework is locally poorly understood and in need of significant revision. Additionally, significant improvement in understanding the internal evolution of terranes can be achieved through targeted studies. For example, some ultramafic complexes (Canil et al., 2003) demarcate subterrane boundaries that were subsequently overprinted and masked by younger tectonism. Improved understanding of the various enigmatic mafic-ultramafic complexes will facilitate evaluation of the Cordilleran tectonic models and their link to economic mineralization. Additionally, metamorphic studies have been instrumental in identifying significant displacement within and between terranes (e.g. Staples et al., 2016).

Yukon-Tanana terrane–parautochthonous North American margin boundaries

Yukon-Tanana terrane is generally accepted to represent an allochthonous terrane that was thrust eastward onto the western Laurentian margin (e.g. Tempelman-Kluit, 1979; Mortensen, 1992); however, the structural thickness of the Yukon-Tanana terrane is poorly constrained, and the combined thickness of it and the Laurentian crust beneath it is estimated to be on the order of only 35 km (Calvert et al., 2017; Hayward, 2019). The Inconnu thrust (Fig. 2) forms the eastern boundary between Yukon-Tanana terrane and parautochthonous North American margin rocks. The Inconnu thrust can be broadly traced for some 450 km of strike length in Yukon alone, and is widely accepted to be the structural leading edge of a shortening-related thrust system that accommodated eastward transport of the Yukon-Tanana terrane onto parautochthonous North American margin. The thrust is relatively easy to delineate on basis of contrasting geology between hanging wall and footwall: Yukon-Tanana terrane in the hanging wall is uniquely characterized by voluminous Early Mississippian to Permian magmatism (Fig. 2), whereas the Laurentian margin in the footwall lacks this magmatism (Selwyn Basin, Cassiar terrane, and the Earn Group; Yukon Geological Survey, 2019). The Inconnu thrust is also spatially associated with intermittent units of the Slide Mountain terrane (Murphy et al., 2006) and rare eclogite occurrences within Yukon-Tanana terrane rocks (e.g. Erdmer et al., 1998; Gilotti et al., 2017). The Yukon-Tanana terrane–parautochthonous North American margin boundary is much more difficult to identify in eastern Alaska and western Yukon because the Yukon-Tanana terrane and parautochthonous North American margin units are much closer in composition, metamorphic grade, and state of deformation (Dusel-Bacon et al., 2006). In this area, the Moose Creek fault likely represents an Inconnu thrust equivalent (*see* 'Moose Creek fault' section, below). If so, the steeply dipping Moose Creek fault must shallow out at depth.

Detailed metamorphic histories also appear to be an effective criteria for discriminating parautochtonous rocks from allocthonous rocks (Hansen and Dusel-Bacon, 1998; Dusel-Bacon et al., 2002; Staples et al., 2016; Ryan et al., 2017). Yukon-Tanana terrane has a Jurassic structural architecture (e.g. Colpron et al., 2015) and records local Mississippian, Permian, and Early Jurassic, amphibolite-facies peak metamorphism, with Early Jurassic cooling (Berman et al., 2007; Staples, 2014; Joyce et al., 2015; Clark, 2017; Ryan et al., 2017, 2018b). In contrast, regional metamorphism and metamorphic cooling ages in parautochthonous North American margin rocks of Yukon and Alaska are dominantly mid-Cretaceous (Dusel-Bacon et al., 2002, Staples et al., 2013, 2016; Jones et al., 2017), but can be as old as middle Jurassic (Ryan et al., 2018b). In the 'Discussion' section, the present authors explore tectonic scenarios to explain the differing metamorphic signature between these Yukon-Tanana terrane and parautochthonous North American margin. In two places where the present study delineated this boundary under the Cordillera project, a strong case can be made that the boundary is reactivated as an extensional structure in the middle Cretaceous (Ryan et al., 2018b; Zagorevski and van Staal, this volume).

Moose Creek fault

The Moose Creek fault is a steep structure in the northern Stevenson Ridge area (Fig. 5) characterized by juxtaposition of parautochthonous North American margin White River assemblage (amphibolite and partially melted metasedimentary rocks) with greenschist-facies Yukon-Tanana terrane volcanic rocks of the Klondike assemblage, and as described earlier, dotted by slivers of mafic-ultramafic rocks along the structural contact (Fig. 2; Ryan et al., 2014). This structure is truncated and largely obliterated by the mid-Cretaceous Dawson Range batholith (Fig. 2, 5), indicating the juxtaposition of Yukon-Tanana terrane and parautochthonous North American margin at this locality in part predates 100 Ma, the age of the batholith (N. Joyce, unpub. data, 2020). Gabbro sills of the Snag Creek suite do not occur north of the Moose Creek fault, thus implying that motion on the Moose Creek fault is post-Late Triassic. The present authors could discern no kinematic information from the rocks along this contact, but interpret the Yukon-Tanana terrane rocks to lie structurally above the parautochthonous North American margin rocks of the White River domain.

Australia Creek fault

As alluded to in the earlier description of the Australia Mountain domain, the Australia Creek fault was interpreted to be a middle Cretaceous lithospheric-scale extensional fault that exhumed a core complex of deep-seated footwall of parautochthonous North American margin through the Yukon-Tanana terrane hanging wall (Staples et al., 2013, 2016). Highly sheared and altered lozenges of ultramafic rocks lie in a high-strain zone at the highest structural level of the penetratively deformed Australia Mountain domain (Fig. 2). The age of the ultramafic rocks is unknown, other than they are pre-middle Cretaceous metamorphism and extensional deformation (Staples et al., 2013). It is possible that they may lie along the original contractional structure related to travel of Yukon-Tanana terrane onto North America in a foreland-propagating orogenic wedge, perhaps in the Early to Middle Jurassic (Staples et al., 2016). The present authors interpret that the ductile shear fabric within the Australia Creek domain formed within a wide shear zone during middle Cretaceous extensional exhumation. Deformation evolved to brittle faulting, leading to the Australia Creek fault as portrayed on Figure 2, being an end-stage brittle feature bounding the Australia Mountain domain core complex. This deformation has obscured the probable original thrust structure speculated upon in Staples et al. (2016). The Stewart River fault bounds the south side of the Australia Creek domain and truncates the Australia Creek fault (Fig. 2). With restoration of 430 km of Paleocene dextral Tintina Fault displacement, the Stewart River fault aligns with the middle Cretaceous North River fault in the Finlayson Lake domain (Fig. 2; Murphy, 2004), begging the question of whether an offset portion of the Australia Mountain domain core complex might yet be recognized in the Finlayson Lake domain.

Major structures internal to the Yukon-Tanana terrane

In addition to faults associated with the boundary between Yukon-Tanana terrane and parautochthonous North American margin, structures were identified over the course of the GEM Cordillera project within the Yukon-Tanana terrane that are of significant scale and tectonic importance. These were located either through field mapping of high-strain zones, or by identifying truncations within map patterns, and were refined using geophysical interpretation or follow-up fieldwork (e.g. Knight et al., 2013; Coleman, 2017; Parsons et al., 2018). Others were identified by results of analytical work such as geochronology, thermochronology, or pressure-temperature work (e.g. Staples et al., 2013).

Willow Lake fault

The Willow Lake fault in the southwest McQuesten map area (Fig. 2, 8) is interpreted to be an extensional structure (Colpron and Ryan, 2010; Ryan et al., 2010) that can be traced for over 100 km as a well defined aeromagnetic low that truncates numerous magnetic anomalies. The fault juxtaposes two crustal domains. On the northeast side of the fault, the Reid Lakes complex is an unmetamorphosed and undeformed Devono-Mississippian assemblage of plutonic and volcanic rocks of the Simpson Range suite and the Finlayson assemblage, respectively. The southwest side includes Snowcap assemblage rocks of Yukon-Tanana terrane, intruded by deformed greenschist- to amphibolite-facies mid-Permian Sulphur Creek suite. The ^{40}Ar/^{39}Ar cooling ages in the Reid Lake complex are as old as Mississippian, whereas cooling ages along the Willow Lake fault and on the southwest side are early to middle Jurassic. This implies that the fault is an extensional structure with northeast-side-down displacement that structurally exhumed mid-crustal rocks as its footwall during in the early Jurassic (Knight et al., 2013). Knight et al. (2013) speculated that this exhumation may have been coeval with Jurassic movements of the Teslin fault system, and likely accommodated crustal thinning. Staples et al. (2016) speculated that the Willow Lake fault is part of a larger core complex–forming exhumation system that cooled in the early Jurassic.

Yukon River shear zone

The Yukon River shear zone (Fig. 2, 5, 8) is a regional-scale, shallowly dipping ductile shear zone that accommodated emplacement of the Mississippian Simpson Range suite–dominated hanging wall over a footwall of Snowcap and Klondike assemblage rocks (Tempelman-Kluit, 1974; Ryan et al., 2014). Permian plutonic rocks and Snowcap assemblage metasedimentary rocks are absent from the immediate hanging wall in the northern Stevenson Ridge area. Late Triassic Pyroxene Mountain suite rocks are restricted to the hanging wall, thus indicating the Yukon River shear zone was active after the Late Triassic (Ryan et al., 2014). The Yukon River shear zone was studied in detail by Coleman (2017) and Parsons et al. (2018) at well exposed shoreline locations along the Yukon River. Parsons et al. (2018) referred to the structure as the Yukon River shear zone, and determined that it initiated as a top-east-southeast mid-crustal shear zone active through a temperature range of 650–440°C and higher, and speculated that it may have been active first as a post-Middle Permian large-scale extensional structure, reactivated as an upper crustal thrust during or after the Early to Middle Jurassic. The Yukon River shear zone projects to the northwest and bounds the geology of the White Gold mineral prospect (Bailey, 2013) within in its footwall. There are no igneous rocks identified in the footwall that are older than Middle Permian (Fig. 2).

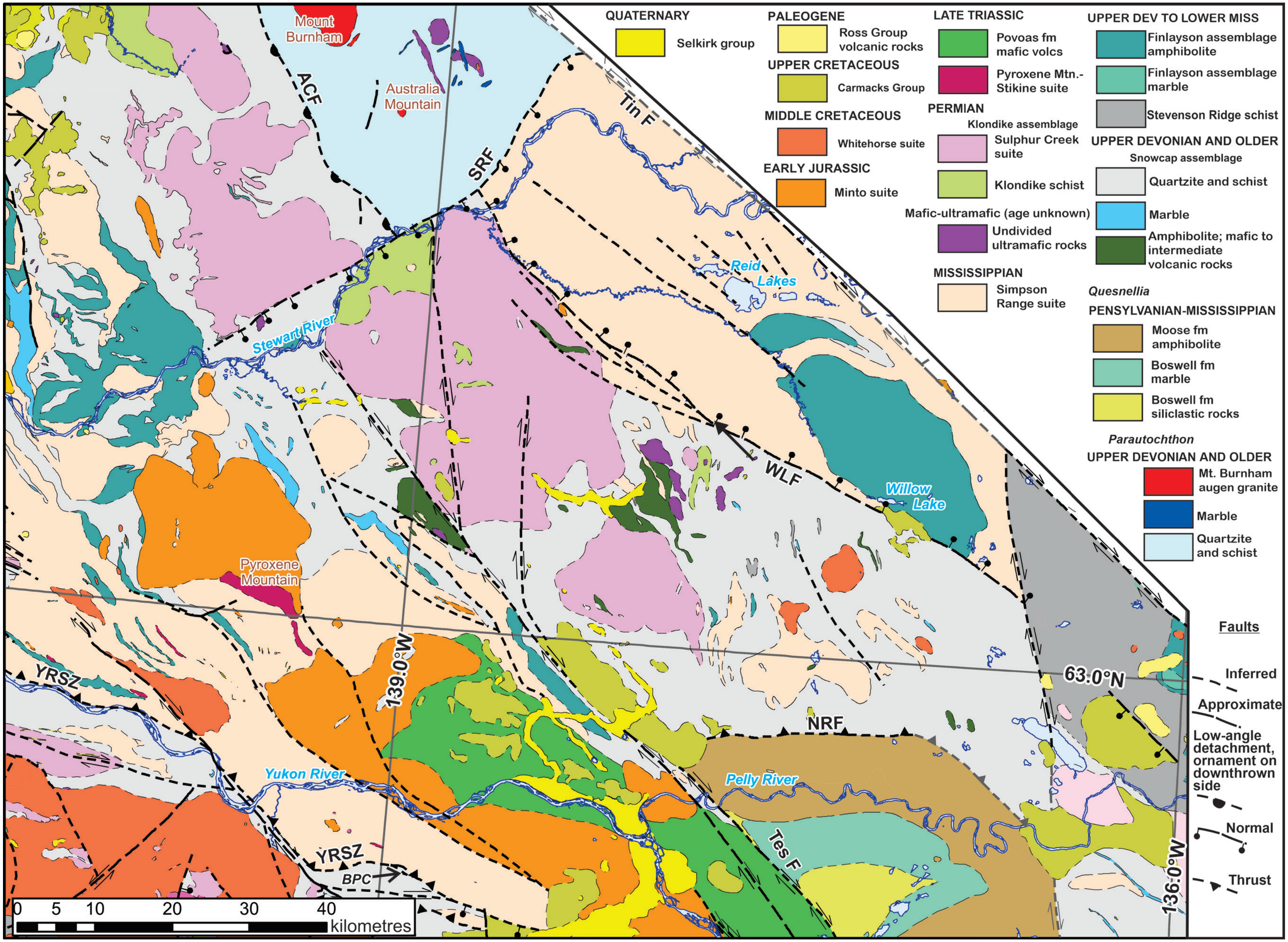

Figure 8. Geology map of southwest McQuesten area highlighting the Willow Lake fault (WLF); the Needlerock fault (NRF), which bounds Paleozoic Quesnellia from Yukon-Tanana terrane; Yukon River shear zone (YRSZ); Teslin Fault (Tes F); and Tintina Fault (Tin F). Parautochthonous North American margin rocks of the Australia Mountain domain are bounded by the Stewart River fault (SRF) and the Australia Creek fault (ACF). BPC = Buffalo Pitts complex, volcs = volcanic rocks, assemb = assemblage, maf to inter = mafic to intermediate, approx. = approximate

Schist Creek fault

The Schist Creek fault through the central part of the Klaza River and Mount Nansen–Nisling River area (Fig. 2, 6) is interpreted to lie on the northwest side of the complex (Fig. 6), traced mainly from aeromagnetic data (Ryan et al., 2016, 2018a). Schist Creek complex peridotite units preserve evidence of shearing at mantle temperatures, prior to its emplacement within the Snowcap assemblage of Yukon-Tanana terrane (Dubman, 2016). The complex is interpreted to have been structurally emplaced along a major detachment fault because there is no evidence of high-temperature contact metamorphism in the surrounding siliciclastic Snowcap assemblage rocks. This differs from the Buffalo Pitts peridotite; in that case Canil et al. (2003) interpreted the high-grade metamorphism of the enveloping Snowcap assemblage country rocks to be due to residual heat derived from emplacement of the peridotite. Early Mississippian Simpson Range suite and Finlayson assemblage rocks outcrop on the southeast side of the Schist Creek fault, whereas intrusions of Permian Sulphur Creek suite are restricted to the northwest side of the fault (*see* Fig. 2); however, the present authors interpret the siliciclastic rocks on both sides of the fault as forming part of the Snowcap assemblage, implying that the Schist Creek fault lies within the Yukon-Tanana terrane. The ^{40}Ar/^{39}Ar cooling ages on either side of the fault are early Jurassic (Joyce et al., in press), indicating that the structure is post-Permian and pre-Early Jurassic (prior to ca. 185 Ma).

DISCUSSION

Studies completed under this project and other recent works (e.g. Ryan, 2014; Clark, 2017; Parsons et al., 2018) highlight a number of possibly crustal-scale structures that occur within the Yukon-Tanana terrane. The scale of and amount of displacement on these structures may not be well constrained, but their nature suggests that the Yukon-Tanana terrane comprises disparate, but likely related crustal fragments.

Intra-terrane structures

Not all of the mafic-ultramafic complexes in Yukon-Tanana terrane are ophiolitic (Zagorevski et al., this volume). Complexes within Yukon-Tanana terrane such as the Buffalo Pitts peridotite (Canil et al., 2003) and the Schist Creek complex (Dubman, 2016; Ryan et al., 2016) represent orogenic peridotite (i.e. exhumed continental lithospheric mantle) that was emplaced into pericratonic continental crust during continental rifting, probably in the Permian (Johnston et al., 2007; Ryan et al., 2016; Parsons et al., 2019). Mantle rocks emplaced into crustal rocks necessitate crustal-scale structures at these locations, however, they are very hard to identify due to reactivation, overprinting deformation, and metamorphism. Such conditions pose difficulties for determining the amount of displacement on such structures. Likewise, for ophiolitic complexes (*see* Zagorevski et al., this volume for a review), the emplacement history typically involves major structures that ultimately separate them from continental terranes. Alternate models for development of Yukon-Tanana terrane tectonic architecture proposed by van Staal et al. (2018) suggest plausible scenarios of Yukon-Tanana terrane comprising a composite terrane of continental basement and juvenile oceanic arc rocks, structurally juxtaposed with suprasubduction zone ophiolitic rocks. In many regions examined under the GEM Cordillera project, structurally bound domains in Yukon-Tanana terrane, each with significantly different character and age, are commonly separated by structural corridors containing strings of mafic-ultramafic lozenges with poorly constrained petrogenesis. The most common manifestation of these associations are domains comprised of Snowcap assemblage siliciclastic rocks with Klondike assemblage plutonic (Sulphur Creek suite) and volcanic rocks (Klondike schist), in fault separation from domains dominated by Mississippian Simpson Range plutonic rocks and Finlayson assemblage metavolanic rocks. The Simpson Range suite and Finlayson assemblage domains are locally isolated from all Snowcap assemblage rocks (e.g. the Yukon River shear zone in the northern Stevenson Ridge area), despite association with Snowcap assemblage in many other areas (e.g. southwest McQuesten and Mount Nansen–Nisling River area). Beyond the basic tectonostratigraphy described for the Snowcap assemblage in Piercey and Colpron (2009), no detailed study has determined its full age range or composition. Consequently, the Snowcap assemblage includes a variety of siliciclastic rocks that may not be closely related. Snowcap assemblage rocks associated with Sulphur Creek suite–Klondike schist domains may be distinct from Simpson Range suite–Finlayson assemblage domains prior to fault juxtaposition. Further analytical work such as detrital geochronology and isotopic characterization may be able to test such hypotheses.

The Yukon River shear zone is the largest intra-terrane structure identified under this project, and the amount of structural overlap between the Simpson Range suite and Finlayson assemblage and Sulphur Creek suite–Klondike schist domains is large (Fig. 2, 9), probably on the scale of 80 to 100 km (Ryan, 2014). Thrust faults of this scale within Yukon-Tanana terrane provide an explanation of its terrane-scale metamorphic characteristics. The Yukon-Tanana terrane has a broad region metamorphosed in the Middle Permian that was exhumed in the Early Jurassic (Berman et al., 2007; Knight et al., 2013; Joyce et al. 2015; Staples et al., 2016); however, middle Permian low-pressure amphibolite metamorphism in the southern Stewart River area is typical of Buchan-type or contact metamorphism, attributed to either an extensional tectonic setting or an active oceanic arc setting (Morneau, 2017). This middle Permian metamorphism slightly postdates the Klondike assemblage magmatism in the region, which may have been partly responsible for some of the metamorphic heat (Morneau, 2017). Buffalo

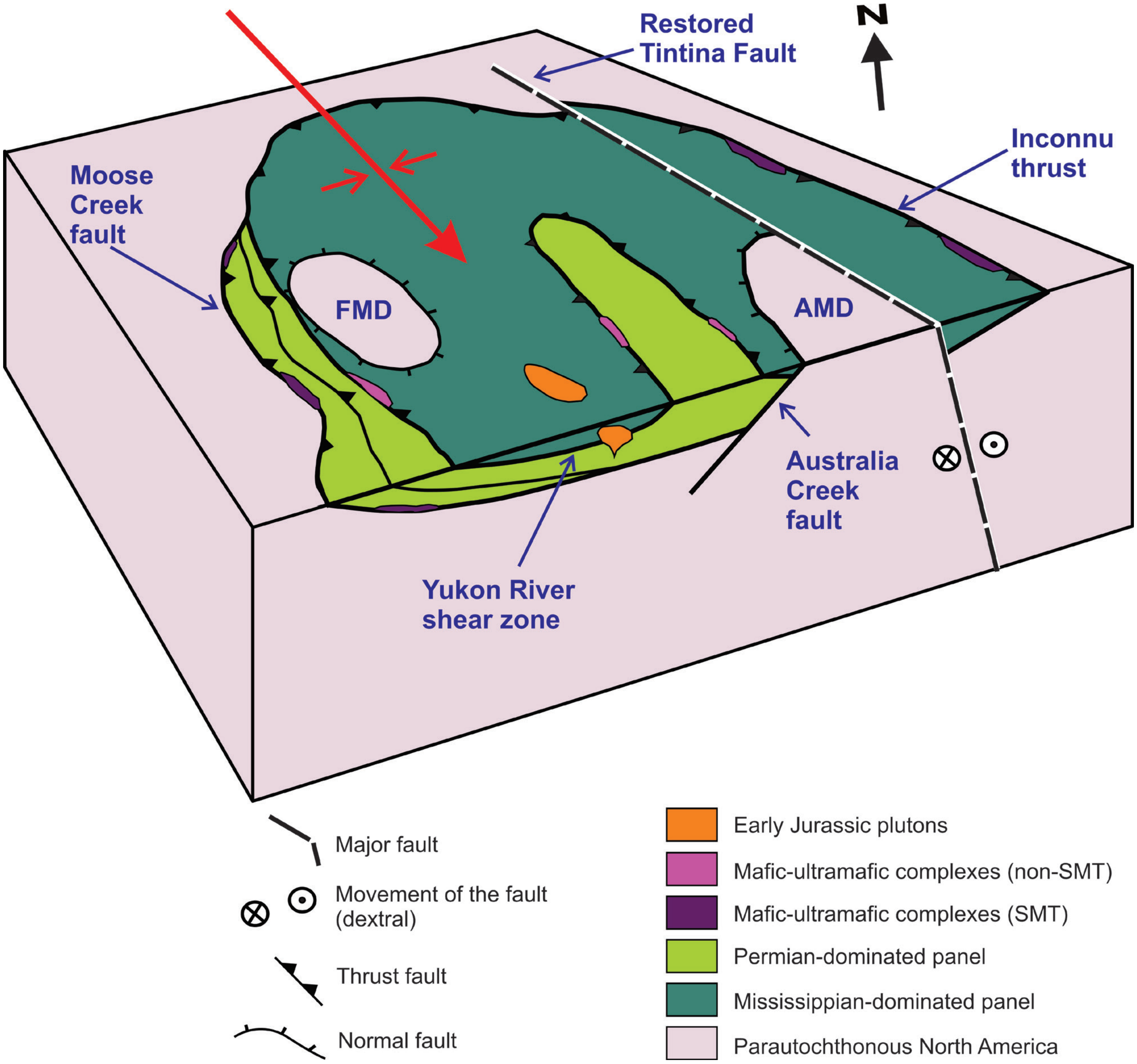

Figure 9. Schematic block diagram of the Yukon-Tanana terrane as a thin flap resting on parautochthonous North America along a Jura-Cretaceous Inconnu thrust, defining a shallowly southeast-plunging regional synformal structure illustrated by the large plunging arrow (red). The equivalent structure on the west side is the Moose Creek fault. The composite Yukon-Tanana terrane shows internal thrust faults (e.g. Yukon River shear zone) cut by Early Jurassic granite. The thrusts are dotted with lozenges of mafic-ultramafic complexes, some from Slide Mountain terrane (SMT) and others are orogenic peridotites. Middle Cretaceous core complexes (AMD = Australia Mountain domain; FMD = Fifty Mile domain) are exhumed along middle Cretaceous faults.

Pitts orogenic peridotite exhumed through Snowcap crust at ca. 260 Ma (Johnston et al., 2007) is indicative of a significant Permian crustal extensional episode. Parsons et al. (2019) proposed that that extension occurred in response to slab break-off and/or orogenic collapse following Middle Permian collision between the Yukon-Tanana terrane and the Dunite Peak intra-oceanic arc. This is also consistent with the finding of Parsons et al. (2018), that the Yukon River shear zone may have first been active as an extensional fault sometime between the Middle Permian and Early Jurassic.

The Willow Lake fault is interpreted to have accommodated widespread Jurassic exhumation of Yukon-Tanana terrane crust (Knight et al., 2013). Prior to exhumation, a latest Triassic burial culminated in Early Jurassic Barrovian metamorphism recorded in the southwest McQuesten area (Staples, 2014) and the Stewart River area (Berman et al., 2007; Morneau, 2017; Morneau et al., 2017). The Yukon River shear zone is likely part of a regional system of thrusts responsible for an internal tectonic thickening event and metamorphism in latest Triassic–Early Jurassic time in Yukon-Tanana terrane, thus preserving small isolated vestiges of mafic-ultramafic tectonic lozenges that may originally have been emplaced within Yukon-Tanana terrane crust along major extensional faults (possibly in the Permian).

A similar structural pattern has emerged from the Mount Nansen–Nisling River, Klaza River, and Aishihik Lake area (Fig. 6), where the Schist Creek fault is spatially associated with lozenges of orogenic peridotite structurally emplaced in the Snowcap assemblage. This indicates the region underwent extension (Dubman, 2016) during or after Middle Permian time (Ryan et al., 2018a). Dominantly Permian magmatic rocks lie on the northwest side of the Schist Creek fault, and dominantly Mississippian magmatic rocks lie on the southeast side. The Schist Creek fault and the Schist Creek complex appear to be moderately to steeply dipping, but the structure's original attitude is unknown. Metamorphic $^{40}Ar/^{39}Ar$ cooling ages on either side of the Schist Creek fault are early Jurassic (185 Ma to 180 Ma; Joyce et al., 2020, in press). Peak metamorphic conditions in Snowcap assemblage rocks west of Aishihik Lake (south of the Schist Creek fault) were determined to be between 200 Ma and 190 Ma by in situ monazite dating, and exhumational decompression occurred between 188 Ma and 175 Ma (Clark, 2017). This demonstrates that a very large region of Yukon-Tanana terrane was exhumed in the early Jurassic, immediately after reaching Barrovian peak metamorphic conditions. Aluminum-in-hornblende geobarometry indicates that the Minto suite was intruded at depths of 21 to 31 km (Topham, 2015). Since these plutons intrude the Late Triassic Lewes River group volcanic rocks (Stikine arc magmatism), the volcanic rocks must have been buried to such depths by the age of the Minto suite plutons, ca. 197 Ma (Sack et al., 2020). Slightly later, ca. 190 to 180 Ma, Long Lake suite intrusions into the Lewes River group and Yukon-Tanana terrane basement (Joyce et al., 2016) indicate that the units had been exhumed to shallower depths of 12 to 17 km (Topham, 2015; Sack et al., 2020) by that time. Continued exhumation passed the units through $^{40}Ar/^{39}Ar$ in biotite and muscovite closure temperatures between 195 Ma and 175 Ma (Joyce et al., 2015; Staples et al., 2016; Clark, 2017; Moher, 2018).

Structures associated with the latest Triassic burial of Yukon-Tanana terrane (Berman et al., 2007) remain elusive, despite their likely occurrence on a regional scale. Likewise the extensional faults (e.g. Willow Lake fault) that accommodated rapid exhumation the Yukon-Tanana terrane in the Early Jurassic were likely regional-scale structures, but have remained difficult to identify due to the overprint of younger (Cretaceous to Paleocene) structures, and burial by younger cover rocks (e.g. Late Cretaceous Carmacks Group).

Yukon-Tanana terrane–parautochthonous North American margin boundary

An architecture of Yukon-Tanana terrane representing a thin flap on a structural basement of parautochthonous North American margin has long been proposed from interpretations of the LITHOPROBE seismic profiles across the northern Cordillera (Cook et al., 2004; Cook and Erdmer, 2005), and recent findings of Hayward (2015) demonstrated that geophysical lineaments in the deep basement of western Yukon continues from known Selwyn Basin basement southwestward under the pericratonic terranes to at least the Denali Fault. Parautochthonous North American margin is exposed in core complexes (e.g. Australia Creek domain; Fifty Mile domain; *see* Fig. 2) through an upper plate of Yukon-Tanana terrane wherein the lower plate was exhumed some 25 to 28 km (Staples et al., 2016), leaving little room for the upper plate allochthon to be thick; perhaps only on the order of a few kilometres.

Results of studies by Cleven and colleagues (N.R. Cleven, J.J. Ryan, D. Kellett, W. McClelland, A. Zagorevski, N. Joyce, J. Crowley, and A. Parsons, unpub. manuscript, 2021) show a remarkably strong similarity in the detrital zircon signatures between Snowcap assemblage samples in Yukon-Tanana terrane, and nearby Scottie Creek formation samples of parautochthonous North American margin in the White River domain. These are separated by the Moose Creek fault (Fig. 2). A possible interpretation is that the Snowcap assemblage is derived from the parautochthonous North American margin rocks — a widely accepted model (e.g. Mortensen, 1992; Colpron et al., 2007). Alternatively, it could be interpreted that the Scottie Creek formation and the Snowcap assemblage are part of the same terrane, so it is important to study their distinctions.

Felsic to intermediate granitoid magmatism in Yukon-Tanana terrane characteristically ranges from as old as 363 Ma (the oldest plutons of the Grass Lakes suite and the Simpson Range suite (Murphy et al., 2006)), through Mississippian and Pennsylvanian, and the ca. 263 to 254 Ma Permian Klondike assemblage (Beranek and Mortensen, 2011). According to geochronology results under the GEM Cordilleran project, felsic to intermediate granitoid magmatism in the White River assemblage ranges from ca. 370 Ma to 363 Ma, thus lacking Mississippian to Permian magmatism, and this is quite distinct from magmatism within Yukon-Tanana terrane. The ca. 230 Ma Snag Creek gabbro suite (Murphy et al., 2009) intruded the White River assemblage (Ryan et al., 2014), similar to gabbro sills in the Delta district of eastern Alaska (Dashevsky et al., 2003; Dusel-Bacon et al., 2006) and the Galena suite gabbro in North American stratigraphy in McQuesten and Mayo areas of Yukon (Murphy, 1997). These are not known to intrude Yukon-Tanana terrane. To the contrary, the younger ca. 220 to 212 Ma Pyroxene Mountain suite (Stikine Suite;

Sack et al., 2020) intruded only the Yukon-Tanana terrane, and is not known in parautochthonous North American margin.

The hanging wall flap of Yukon-Tanana terrane and the footwall parautochthonous North American margin have very distinct metamorphic and cooling histories. The hanging wall records Permian to Early Jurassic metamorphism, with Early Jurassic cooling (Dusel-Bacon et al., 2002; Joyce et al., 2016; Staples et al., 2016; Jones et al., 2017; Ryan et al., 2017). The age of metamorphism in the White River assemblage is not as well constrained; however, the Snag Creek gabbro is locally strongly deformed, indicating post-230 Ma deformation (Ryan et al., 2014). The $^{40}Ar/^{39}Ar$ cooling ages for two localities in the westernmost White River domain give middle Cretaceous cooling ages of ca. 114.1 ± 0.7 Ma and 109.2 ± 0.6 Ma (Yukon Geological Survey, 2019) that are similar to cooling ages in parautochthonous North American margin rocks such as the Fifty Mile domain and the Australia Mountain domain (Staples et al., 2013, 2016). Similar metamorphic age relationships have been reported by Jones et al. (2017) and Jones and Kreiner (2019) for Yukon-Tanana terrane and parautochthonous North American margin in eastern Alaska where allochthonous Yukon-Tanana terrane rocks yield Jurassic and older $^{40}Ar/^{39}Ar$ ages, compared to consistent mid-Cretaceous cooling ages in parautochthonous North American margin assemblages. The present authors therefore conclude that the Yukon-Tanana terrane–parautochthonous North American margin boundary on the north side of the White River complex, the Moose Creek fault (Fig. 5) is, in essence, the equivalent of the Jura-Cretaceous Inconnu thrust, but exposed on the southwest side of the Yukon-Tanana terrane allochthon, and has been strongly reactivated as a middle Cretaceous extensional fault immediately prior to intrusion of the Dawson Range batholith (Ryan et al., 2018b).

The Yukon-Tanana terrane—parautochthonous North American margin structural boundary wraps around the northwest end of Yukon-Tanana terrane in eastern Alaska as portrayed in Figures 4 and 6 of Murphy (2018). This aligns well with the Inconnu thrust on the eastern side of the pericratonic terranes with restoration of about 450 km of dextral displacement along the Tintina Fault (Fig. 2, 9). Recent characterization of parautochthonous North American margin rocks east of the Inconnu thrust in the Hyland River area of southeast Yukon demonstrates that its Proterozoic to Paleozoic stratigraphy were deformed and metamorphosed between greenschist and amphibolite facies at ca. 107 Ma, and cooled prior to subsequent intrusions at ca. 97 Ma (Moynihan, 2016, 2017). This is consistent with ages of metamorphism and cooling in the Australia Mountain domain, the White River assemblage, as well as in the Lake George assemblage of eastern Alaska (Dusel-Bacon et al., 2002; Staples et al., 2016; Jones et al., 2017), but is not an age of metamorphism known in Yukon-Tanana terrane in Yukon.

Implications for the development of the northern Cordillera

In addition to modernizing the geological framework through a number of mapping activities across southern Yukon, research under the Cordilleran project has added to the understanding of the role of the Yukon-Tanana terrane in development of the northern Cordillera. The tectonostratigraphic framework of Colpron et al. (2007) provides a fundamental starting point, but local deviations from the framework indicate that Yukon-Tanana terrane is a composite terrane composed of Permian-dominated domains, separated from Mississippian-dominated domains, and possibly even continental-dominated domains separated from domains of juvenile oceanic arc–back-arc complex (van Staal et al., 2018). Structurally bound domains of Yukon-Tanana terrane can be better defined through targeted geochronology, geochemistry, and isotopic geochemistry. The nature of structures highlighted by mafic-ultramafic complexes, some of which have been proven to be derived from the mantle and emplaced into crustal assemblages, require crustal-scale displacements to accommodate known relationships. In the future, a more detailed and complete study of the stratigraphy of the Snowcap assemblage may be able to further define the composite nature of the terrane. The range of lithologies derived from the North American margin represented in the Snowcap assemblage must be determined to provide more realistic models for the tectonic setting of formation for Yukon-Tanana terrane.

It is possible that some geological domains currently included in Yukon-Tanana terrane are parts of Paleozoic Stikinia, structurally interleaved with Yukon-Tanana terrane. An example of this is a belt of ca. 346 to 344 Ma Mississippian plutons that extend from the northern Stevenson Ridge area, into the Stewart River area (N. Joyce, unpub. data, 2020), and lack any inherited zircon (which would be uncommon for Yukon-Tanana terrane magmatism). These plutons are currently included as part of the Simpson Range suite, however, they do occur southwest of the main belt of Simpson Range plutons that exhibit common zircon inheritance. This age and lack of inherited zircon is characteristic of Mississippian plutons associated with the Stikine assemblage in northern British Columbia (Gunning et al., 2006). If this domain is in fact a sliver of Paleozoic Stikinia, it was probably interleaved prior to Early Jurassic cooling, as defined by their common $^{40}Ar/^{39}Ar$ ages.

CONCLUSIONS

Regional geological map relationships indicate that the pericratonic terranes (particularly the areally extensive Yukon-Tanana terrane) form a relatively thin klippe on a footwall of semicontinuous parautochthonous North American margin that extends southwest of the nappe to at least the Denali Fault (Fig. 2). Structural windows through the thinned allochthonous upper plate (the Yukon-Tanana terrane) expose parautochthonous North American margin in west-central Yukon and eastern Alaska as mid-Cretaceous extensional core complexes (Fig. 9). The Yukon-Tanana terrane is founded on Snowcap assemblage basement that is very similar in composition and age to Late Devonian rocks of the parautochthonous North American margin, making their discrimination difficult. The detrital zircon characteristics of Yukon-Tanana terrane discussed herein suggest that Yukon-Tanana terrane did not originate a great distance from its final tectonic resting place upon the parautochthonous North American margin rocks; this raises the question of how wide the intervening Slide Mountain Ocean could have been.

The intensity of deformation in both parautochthonous North American margin and Yukon-Tanana terrane makes it difficult to distinguish contractional and extensional structures, and commonly where the structural contacts are precisely located. The timing of middle to upper amphibolite-facies regional metamorphism recorded in both parautochthonous North American margin and Yukon-Tanana terrane is not everywhere well constrained; however, distinct patterns have emerged. The parautochthonous North American margin is characterized by Late Devonian metasedimentary successions with voluminous latest Devonian to earliest Mississippian plutons, with a lack of Mississippian to middle Permian magmatism, and records Middle Jurassic to mid-Cretaceous metamorphism. In contrast, the Yukon-Tanana terrane is characterized by voluminous Mississippian to middle Permian magmatism, and records Mississippian to Middle Jurassic metamorphism and tectonism, which are absent in parautochthonous North American margin.

Yukon-Tanana terrane is a composite terrane, wherein major regional structures such as the Yukon River shear zone and the Schist Creek fault appear to juxtapose domains dominated by distinct Mississippian and Permian magmatism. These structures are dotted with lozenges of mafic-ultramafic complexes, at least two of which are interpreted as orogenic peridotite derived from sublithospheric mantle. Whereas these structures appear to place Mississippian rocks over Permian rocks, probably in the latest Triassic, they may reactivate structures that were originally Permian transcrustal extensional structures.

ACKNOWLEDGMENTS

Over the years of this project the authors greatly acknowledge geological discussions with colleagues and collaborators including C. van Staal, M. Colpron, D. Murphy, J. Nelson, J. Jones, C. Roots, W. McClelland, M. Allan, S. Israel, D. Gibson, and J. Mortensen. S. Williams is thanked for GIS services over the life of the project. This manuscript benefitted by thoughtful reviews by C. van Staal and N. Hayward.

REFERENCES

Abbott, G., 1983. Origin of the Clinton Creek asbestos deposit; *in* Yukon Exploration and Geology 1982; Exploration and Geological Services Division; Indian and Northern Affairs Canada, Yukon, p. 18–25.

Allan, M.M., Mortensen, J.K., Hart, C.J.R., Bailey, L.A., Sanchez, M.G., Ciolkiewicz, W., McKenzie, G.G., and Creaser, R.A., 2013. Magmatic and metallogenic framework of west-central Yukon and eastern Alaska; Society of Economic Geologists, Special Publication 17, p. 111–168.

Bailey, L.A., 2013. Late Jurassic fault-hosted gold mineralization of the Golden Saddle deposit, White Gold district, Yukon Territory; M.Sc. thesis, The University of British Columbia, Vancouver, British Columbia, 170 p.

Beranek, L.P. and Mortensen, J.K., 2011. The timing and provenance record of the Late Permian Klondike orogeny in northwestern Canada and arc-continent collision along western North America; Tectonics, v. 30, issue 5. https://doi.org/10.1029/2010TC002849

Beranek, L.P., van Staal, C.R., McClelland, W.C., Israel, S., and Mihalynuk, M.G., 2013. Baltican crustal provenance for Cambrian–Ordovician sandstones of the Alexander terrane, North American Cordillera: evidence from detrital zircon U–Pb geochronology and Hf isotope geochemistry; Journal of the Geological Society, v. 170, p. 7–18. https://doi.org/10.1144/jgs2012-028

Berman, R.G., Ryan, J.J., Gordey, S.P., and Villeneuve, M., 2007. Permian to Cretaceous polymetamorphic evolution of the Stewart River region, Yukon-Tanana terrane, Yukon, Canada: P-T evolution linked with in-situ SHRIMP monazite geochronology; Journal of Metamorphic Geology, v. 25, p. 803–827. https://doi.org/10.1111/j.1525-1314.2007.00729.x

Calvert, A.J., Hayward, N., Vayavur, R., and Colpron, M., 2017. Seismic and gravity constraints on the crustal architecture of the Intermontane terranes, central Yukon; Canadian Journal of Earth Sciences, v. 54, p. 798–811. https://doi.org/10.1139/cjes-2016-0189

Canil, D. and Johnston, S.T., 2003. Harzburgite Peak: a large mantle tectonite massif in ophiolite from southwest Yukon; *in* Yukon Exploration and Geology 2002, (ed.) D.S. Emond and L.L. Lewis; Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 77–84.

Canil, D., Johnston, S.T., Evers, K., Shellnutt, J.G., and Creaser, R.A., 2003. Mantle exhumation in an Early Paleozoic passive margin, northern Cordillera, Yukon; The Journal of Geology, v. 111, p. 313–327. https://doi.org/10.1086/373971

Cawood, P.A., Kröner, A., Collins, W.J., Kusky, T.M., Mooney, W.D., and Windley, B.F., 2009. Accretionary orogens through Earth history; Geological Society of London, Special Publications, v. 318, p. 1–36. https://doi.org/10.1144/SP318.1

Clark, A.D., 2017. Tectonometamorphic history of mid-crustal rocks at Aishihik Lake, southwest Yukon; M.Sc. thesis, Simon Fraser University, Burnaby, British Columbia, 153 p.

Cleven, N., Ryan, J., Zagorevski, A., and Hayward, N., 2018. Revised tectonostratigraphy of Yukon Tanana and Slide Mountain terrane units in the Thirtymile Range and Wolf Lake areas, southern Yukon: GEM-2 Cordillera project, report of activities 2018; Geological Survey of Canada, Open File 8476, 13 p. https://doi.org/10.4095/311323

Cobbett, R., 2015. Geological map of the Anvil Lake area, central Yukon, parts of NTS 105K/11 and 105K/12; Yukon Geological Survey, Open File 2015-2, scale 1:50 000.

Cobbett, R., 2016. Geological map of the Earn Lake area, central Yukon, parts of NTS 105L/9, 15 and 16; Yukon Geological Survey, Open File 2016-40, scale 1:50 000.

Coleman, M.J., 2017. Structural and petrofabric analysis of the Yukon River Thrust Fault, west-central Yukon; B.Sc. thesis, Simon Fraser University, Burnaby, British Columbia, 82 p.

Colpron, M. and Nelson, J.L., 2011. A digital atlas of terranes for the northern Cordillera; British Columbia Ministry of Energy and Mines, British Columbia Geological Survey GeoFile 2011-11 [http://www.geology.gov.yk.ca] (accessed January 15, 2020).

Colpron, M. and Ryan, J.J., 2010. Bedrock geology of southwest McQuesten (NTS 115P) and part of northern Carmacks (NTS 115I) map area; *in* Yukon Exploration and Geology, (ed.) K.E. MacFarlane, L.H. Weston, and L.R. Blackburn; Yukon Geological Survey, p. 159–184.

Colpron, M., Nelson, J.L., and Murphy, D.C., 2006a. A tectonostratigraphic framework for the pericratonic terranes of the northern Canadian Cordillera; *in* Paleozoic Evolution and Metallogeny of Pericratonic Terranes at the Ancient Pacific Margin of North America, Canadian and Alaskan Cordillera, (ed.) M. Colpron and J.L. Nelson; Geological Association of Canada, Special Paper 45, p. 1–23.

Colpron, M., Mortensen, J.K., Gehrels, G.E., and Villeneuve, M., 2006b. Basement complex, Carboniferous magmatism and Paleozoic deformation in Yukon-Tanana terrane of central Yukon: field, geochemical and geochronological constraints from Glenlyon map area; *in* Paleozoic Evolution and Metallogeny of Pericratonic Terranes at the Ancient Pacific Margin of North America, Canadian and Alaskan Cordillera, (ed.) M. Colpron and J.L. Nelson; Geological Association of Canada, Special Paper 45, p. 131–151.

Colpron, M., Nelson, J.L., and Murphy, D.C., 2007. Northern Cordilleran terranes and their interactions through time; GSA Today, v. 17, p. 4–10. https://doi.org/10.1130/GSAT01704-5A.1

Colpron, M., Crowley, J.L., Gehrels, G., Long, D.G., Murphy, D.C., Beranek, L., and Bickerton, L., 2015. Birth of the northern Cordilleran orogen, as recorded by detrital zircons in Jurassic synorogenic strata and regional exhumation in Yukon; Lithosphere, v. 7, no. 5, p. 541–562. https://doi.org/10.1130/L451.1

Coney, P.J., Jones, D.L., and Monger, J.W.H., 1980. Cordilleran suspect terranes; Nature, v. 288, p. 329–333. https://doi.org/10.1038/288329a0

Cook, F.A. and Erdmer, P.A., 2005. An 1800 km cross section of the lithosphere through the northwestern North American plate: lessons from 4.0 billion years of Earth's history; Canadian Journal of Earth Sciences, v. 42, p. 1295–1311. https://doi.org/10.1139/e04-106

Cook, F.A., Clowes, R.M., Snyder, D.B., van der Velden, A.J., Hall, K.W., Erdmer, P., and Evenchick, C.A., 2004. Precambrian crust beneath the Mesozoic northern Canadian Cordillera discovered by Lithoprobe seismic reflection profiling; Tectonics, v. 23, cit. no. TC2010. https://doi.org/10.1029/2002TC001412

Creaser, R.A., Heaman, L.M., and Erdmer, P., 1997. Timing of high-pressure metamorphism in the Yukon–Tanana terrane, Canadian Cordillera: constraints from U-Pb zircon dating of eclogite from the Teslin tectonic zone; Canadian Journal of Earth Sciences, v. 34, p. 709–715. https://doi.org/10.1139/e17-057

Creaser, R.A., Goodwin-Bell, J.-A.S., and Erdmer, P., 1999. Geochemical and Nd isotopic constraints for the origin of eclogite protoliths, northern Cordillera; implications for the Paleozoic tectonic evolution of the Yukon-Tanana Terrane; Canadian Journal of Earth Sciences, v. 36, p. 1697–1709. https://doi.org/10.1139/e99-070

Dashevsky, S.S., Schaefer, C.F., and Hunter, E.N., 2003. Bedrock geologic map of the Delta Mineral Belt, Tok mining district, Alaska; Alaska Division of Geological and Geophysical Surveys, Professional Report 122, 128 p.

Devine, F., Carr, S.D., Murphy, D.C., Davis, W.J., Smith, S., and Villeneuve, M.E., 2006. Geochronological and geochemical constraints on the origin of the Klatsa metamorphic complex: implications for Early Mississippian high-pressure metamorphism within Yukon-Tanana terrane; *in* Paleozoic Evolution and Metallogeny of Pericratonic Terranes at the Ancient Pacific Margin of North America, Canadian and Alaskan Cordillera, (ed.) M. Colpron and J.L. Nelson; Geological Association of Canada, Special Paper 45, p. 107–130.

Dubman, M., 2016. Petrogenesis and significance of the Schist Creek mafic-ultramafic complex, southwest Yukon; B.Sc. thesis, Simon Fraser University, Burnaby, British Columbia, 73 p.

Dusel-Bacon, C. and Williams, I.S., 2009. Evidence for prolonged mid-Paleozoic plutonism and ages of crustal sources in east-central Alaska from SHRIMP U-Pb dating of syn-magmatic, inherited and detrital zircon; Canadian Journal of Earth Sciences, v. 46, p. 21–39. https://doi.org/10.1139/E09-005

Dusel-Bacon, C., Lanphere, M.A., Sharp, W.D., Layer, P.W., and Hansen, V.L., 2002. Mesozoic thermal history and timing of structural events for the Yukon-Tanana Upland, east-central Alaska: ^{40}Ar/^{39}Ar data from metamorphic and plutonic rocks; Canadian Journal of Earth Sciences, v. 39, p. 1013–1051. https://doi.org/10.1139/e02-018

Dusel-Bacon, C., Hopkins, M.J., Mortensen, J.K., Dashevsky, S.S., Bressler, J.R., and Day, W.C., 2006. Paleozoic tectonic and metallogenic evolution of the pericratonic rocks of east-central Alaska and adjacent Yukon; *in* Paleozoic Evolution and Metallogeny of Pericratonic Terranes at the Ancient Pacific Margin of North America, Canadian and Alaskan Cordillera, (ed.) M. Colpron and J.L. Nelson; Geological Association of Canada, Special Paper 45, p. 25–74.

Dusel-Bacon, C., Holm-Denoma, C.S., Jones, J.V., Aleinikoff, J.N., and Mortensen, J.K., 2017. Detrital zircon geochronology of quartzose metasedimentary rocks from parautochthonous North America, east-central Alaska; Lithosphere, v. 9, p. 927–952. https://doi.org/10.1130/L672.1

Erdmer, P., Ghent, E.D., Archibald, D.A., and Stout, M.Z., 1998. Paleozoic and Mesozoic high pressure metamorphism at the margin of ancestral North America in central Yukon; Geological Society of America Bulletin, v. 110, p. 615–629. https://doi.org/10.1130/0016-7606(1998)110%3c0615:PAMHPM%3e2.3.CO%3b2

Foster, H.L., Keith, T.E.C., and Menzie, W.D., 1994. Geology of the Yukon-Tanana area of east-central Alaska; *in* The Geology of Alaska, (ed.) G. Plafker and H.C. Berg: Geological Society of America, The Geology of North America, v. G-1, p. 205–240. https://doi.org/10.1130/DNAG-GNA-G1.205

Gabrielse, H., Monger, J.W.H., Wheeler, J.O., and Yorath, C.J., 1991. Part A- Morphogeological belts, tectonic assemblages and terranes; Chapter 2 *in* Geology of the Cordilleran Orogen in Canada, (ed.) H. Gabrielse and C.J. Yorath; Geological Survey of Canada, Geology of Canada, no. 4, p. 15–28 (*also* Geological Society of America, The Geology of North America, v. G-2). https://doi.org/10.4095/134073

Gabrielse, H., Murphy, D.C., Mortensen, J.K., Haggart, J.W., Enkin, R.J., and Monger, J., 2006. Cretaceous and Cenozoic dextral orogen-parallel displacements, magmatism, and paleogeography, north-central Canadian Cordillera; *in* Paleogeography of the North American Cordillera: evidence for and against large-scale displacements, (ed.) J.W. Haggart, R.J. Enkin, and J.W.H. Monger; Geological Association of Canada, Special Paper 46, p. 255–276.

Gehrels, G. and Pecha, M., 2014. Detrital zircon U-Pb geochronology and Hf isotope geochemistry of Paleozoic and Triassic passive margin strata of western North America; Geosphere, v. 10, p. 49–65. https://doi.org/10.1130/GES00889.1

Gehrels, G.E., McClelland, W.C., Samson, S.D., and Patchett, P.J., 1991. U-Pb geochronology of detrital zircons from a continental margin assemblage in the northern Coast Mountains, southeastern Alaska; Canadian Journal of Earth Sciences, v. 28, p. 1285–1300. https://doi.org/10.1139/e91-114

Gilotti, J.A., McClelland, W.C., van Staal, C.R., and Petrie, M.B., 2017. Detrital zircon evidence for eclogite formation by basal subduction erosion – an example from the Yukon-Tanana composite arc, Canadian Cordillera; *in* The Crust-Mantle and Lithosphere-Asthenosphere Boundaries: Insights from Xenoliths, Orogenic Deep Sections, and Geophysical Studies, (ed.) G. Bianchini, J.-L. Bodinier, R. Braga, and M. Wilson; Geological Society of America, Special Paper 526, p. 173–189. https://doi.org/10.1130/2017.2526(09)

Gordey, S.P. and Ryan, J.J., 2005. Geology, Stewart River area (115N, 115-O and part of 115J), Yukon Territory; Geological Survey of Canada, Open File 4970, scale 1:250 000. https://doi.org/10.4095/221149

Gunning, M.H., Hodder, R.W. and Nelson, J.L., 2006. Contrasting volcanic styles and their tectonic implications for the Paleozoic Stikine Assemblage, western Stikine Terrane, northwestern British Columbia; *in* Paleozoic Evolution and Metallogeny of Pericratonic Terranes at the Ancient Pacific Margin of North America, Canadian and Alaskan Cordillera, (ed.) M. Colpron and J.L. Nelson; Geological Association of Canada, Special Paper 45, p. 201–227.

Hadlari, T., Davis, W.J., Dewing, K., Heaman, L.M., Lemieux, Y., Ootes, L., Pratt, B.R., and Pyle, L.J., 2012. Two detrital zircon signatures for the Cambrian passive margin of northern Laurentia highlighted by new U-Pb results from northern Canada; Geological Society of America Bulletin, v. 124, p. 1155–1168. https://doi.org/10.1130/B30530.1

Hansen, V.L. and Dusel-Bacon, C., 1998. Structural and kinematic evolution of the Yukon-Tanana upland tectonites, east-central Alaska: a record of late Paleozoic to Mesozoic crustal assembly; Geological Society of America Bulletin, v. 110, p. 211–230. https://doi.org/10.1130/0016-7606(1998)110%3c0211:SAKEOT%3e2.3.CO%3b2

Hart, C.J.R., 1997. A transect across northern Stikinia: geology of the northern Whitehorse map area, southern Yukon Territory (105D/13-16); Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Bulletin 8, 112 p.

Hawkesworth, C., Cawood, P., Kemp, T., Storey, C., and Dhuime, B., 2009. A matter of preservation; Science, v. 323, no. 5910, p. 49–50. https://doi.org/10.1126/science.1168549

Hayward, N., 2015. Geophysical investigation and reconstruction of lithospheric structure and its control on geology, structure, and mineralization in the Cordillera of northern Canada and eastern Alaska; Tectonics, v. 34, p. 2165–2189. https://doi.org/10.1002/2015TC003871

Hayward, N., 2019. The 3D geophysical investigation of a Middle Cretaceous to Paleocene regional décollement in the Cordillera of northern Canada and Alaska; Tectonics, v. 38, p. 307–334. https://doi.org/10.1029/2018TC005295

Hunt, J.A., 2002. Volcanic-associated massive sulphide (VMS) mineralization in the Yukon-Tanana Terrane and coeval strata of the North American miogeocline, in the Yukon and adjacent areas; Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Bulletin 12, 107 p.

Johnston, S.T., Canil, D.C., and Heaman, L.A., 2007. Permian exhumation of the Buffalo Pitts orogenic peridotite massif, northern Cordillera, Yukon; Canadian Journal of Earth Sciences, v. 44, p. 275–286. https://doi.org/10.1139/e06-078

Jones, J.V. and Kreiner, D., 2019. Tectonic evolution and metallogeny of the Yukon-Tanana upland, eastern Alaska: recent USGS findings and future directions; *in* Cordilleran Tectonics Workshop, Vancouver, British Columbia, February 22–24, 2019, Program with Abstracts, p. 9–10.

Jones, J.V., Caine, J.S., Holm-Denoma, C.S., Ryan, J.J., Benowitz, J.A., and Drenth, B.J., 2017. Unraveling the boundary between the Yukon-Tanana terrane and parautochthonous North America in eastern Alaska; Geological Society of America; Geological Association of Canada, Program with Abstracts, v. 49, no. 6. https://doi.org/10.1130/abs/2017AM-304142

Joyce, N.L., Ryan, J.J., Colpron, M., Hart, C.J.R., and Murphy, D.C., 2015. A compilation of $^{40}Ar/^{39}Ar$ age determinations for igneous and metamorphic rocks, and mineral occurrences from central and southeast Yukon; Geological Survey of Canada, Open File 7924, 229 p. https://doi.org/10.4095/297446

Joyce, N.L., Colpron, M., Allan, M.M., Sack, P.J., Crowley, J.L., and Chapman, J.B., 2016. New U-Pb zircon dates from the Aishihik batholith, southern Yukon; *in* Yukon Exploration and Geology 2015, (ed.) K.E. MacFarlane and M.G. Nordling; Yukon Geological Survey, p. 131–149, plus digital appendices.

Joyce, N.L., Iraheta Muniz, P., Rayner, N.M., and Ryan, J.J., 2020. Geochronology of the Mount Nansen-Nisling River area, Yukon; Geological Survey of Canada, Open File 8614, 28 p. https://doi.org/10.4095/321802

Joyce, N.L., Iraheta Muniz, P., Kellett, D.A., Rayner, N.M., and Ryan, J.J., in press. Geochronology of the Klaza River area, Yukon; Geological Survey of Canada, Open File 8615, 38 p. https://doi.org/10.4095/321893

Knight, E., Schneider, D.A., and Ryan, J.J., 2013. Thermochronology of the Yukon-Tanana terrane, west-central Yukon: evidence for Jurassic extension and exhumation in the northern Canadian Cordillera; The Journal of Geology, v. 121, p. 371–400. https://doi.org/10.1086/670721

Logan, J.M. and Mihalynuk, M.G., 2014. Tectonic controls on early Mesozoic paired alkaline porphyry deposit belts (Cu-Au + or - Ag-Pt-Pd-Mo) within the Canadian Cordillera; Economic Geology and the Bulletin of the Society of Economic Geologists, v. 109, p. 827–858. https://doi.org/10.2113/econgeo.109.4.827

Logan, J.M., Drobe, J.R., and McClelland, W.C., 2000. Geology of the Forrest Kerr-Mess Creek area, northwestern British Columbia (NTS 104B/10, 15 & 104G/2 & 7W); British Columbia Ministry of Energy and Mines Energy and Minerals Division Geological Survey Branch, Bulletin 104, 164 p.

Lowey, G.W. and Hills, L.V., 1988. Lithofacies, petrography, and environments of deposition, Tantalus Formation (Lower Cretaceous) Indian River area, west-central Yukon; Bulletin of Canadian Petroleum Geology, v. 36, p. 296–310.

Moecher, D.P. and Samson, S.D., 2006. Differential zircon fertility of source terranes and natural bias in the detrital zircon record: implications for sedimentary provenance analysis; Earth and Planetary Science Letters, v. 247, p. 252–266. https://doi.org/10.1016/j.epsl.2006.04.035

Moher, M., 2018. (U-Th)/He thermochronology of the Aishihik batholith, central Yukon: evidence for stable crust in the Cretaceous; MSc. thesis, University of Ottawa, Ottawa, Ontario, 76 p.

Monger, J.W.H. and Price, R.A., 2002. The Canadian Cordillera: geology and tectonic evolution; Canadian Society of Exploration Geophysicists Recorder, v. 27, February, p. 17–36.

Monger, J.W.H., Price, R.A., and Tempelman-Kluit, D.J., 1982. Tectonic accretion and the origin of the two major metamorphic and tectonic welts in the Canadian Cordillera; Geology, v. 10, p. 70–75. https://doi.org/10.1130/0091-7613(1982)10%3c70:TAATOO%3e2.0.CO%3b2

Morneau, Y.E., 2017. Tectono-metamorphic evolution of the Snowcap assemblage, Yukon-Tanana Terrane, west-central Yukon; M.Sc. thesis, Carleton University, Ottawa, Ontario, 198 p.

Morneau, Y.E., Gaidies, F., Ryan, J.J., and Zagorevski, A., 2017. Estimates of garnet crystallization and rates of metamorphism for metapelites of the Snowcap assemblage, Yukon-Tanana terrane, Yukon; Geological Survey of Canada, Current Research 2017-2, 21 p. https://doi.org/10.4095/304229

Mortensen, J.K., 1990. Geology and U-Pb geochronology of the Klondike District, west-central Yukon Territory; Canadian Journal of Earth Sciences, v. 27, p. 903–914. https://doi.org/10.1139/e90-093

Mortensen, J.K., 1992. Pre-mid-Mesozoic tectonic evolution of the Yukon-Tanana terrane, Yukon and Alaska; Tectonics, v. 11, p. 836–853. https://doi.org/10.1029/91TC01169

Mortensen, J.K., Dusel-Bacon, C., Hunt, J.A., and Gabites, J., 2006. Lead isotopic constraints on the metallogeny of middle and late Paleozoic syngenetic base-metal occurrences in the Yukon-Tanana and Slide Mountain/Seventymile terranes and adjacent portions of the North American miogeocline; *in* Paleozoic Evolution and Metallogeny of Pericratonic Terranes at the Ancient Pacific Margin of North America, Canadian and Alaskan Cordillera, (ed.) M. Colpron and J.L. Nelson; Geological Association of Canada, Special Paper 45, p. 261–279.

Moynihan, D., 2016. Bedrock geology of the upper Hyland River area, NTS 105H/07, 105H/09, 105H/10, 106H/15,105H/16,105I/02, southeast Yukon; Yukon Geological Survey, Open File 2016-36, scale 1:50 000.

Moynihan, D., 2017. Progress report on geological mapping in the upper Hyland River region of southeastern Yukon (parts of NTS 105H/08,09,10,15,16 and 105I/02); *in* Yukon Exploration and Geology 2016, (ed.) K.E. MacFarlane and L.H. Weston; Yukon Geological Survey, p. 163–180.

Murphy, D.C., 1997. Geology of the McQuesten River region, northern McQuesten and Mayo map areas, Yukon Territory (115P/14, 15, 16; 105M/13, 14); Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Bulletin 6, 122 p.

Murphy, D.C., 2004. Devonian-Mississippian metavolcanic stratigraphy, massive sulphide potential and structural re-interpretation of Yukon-Tanana terrane south of the Finlayson Lake massive sulphide district, southeastern Yukon (105G/1, 105H/3,4,5); *in* Yukon Exploration and Geology 2003, (ed.) D.S. Emond and L.L. Lewis; Yukon Geological Survey, p. 157–175.

Murphy, D.C., 2018. Latest Cretaceous–early Eocene Pacific-Arctic?-Atlantic connection: co-evolution of strike-slip fault systems, oroclines, and transverse fold-and-thrust belts in the northwestern North American Cordillera; *in* Circum-Arctic Structural Events: Tectonic Evolution of the Arctic Margins and Trans-Arctic Links with Adjacent Orogens, (ed.) K. Piepjohn, J.V. Strauss, L. Reinhardt, and W.C. McClelland; Geological Society of America, Special Paper 541, p. 1–2. https://doi.org/10.1130/2018.2541(28)

Murphy, D.C., Mortensen, J.K., Piercey, S.J., Orchard, M.J., and Gehrels, G.E., 2006. Mid-Paleozoic to early Mesozoic tectonostratigraphic evolution of Yukon-Tanana and Slide Mountain terranes and affiliated overlap assemblages, Finlayson Lake massive sulphide district, southeastern Yukon; *in* Paleozoic Evolution and Metallogeny of Pericratonic Terranes at the Ancient Pacific Margin of North America, Canadian and Alaskan Cordillera, (ed.) M. Colpron and J.L. Nelson; Geological Association of Canada, Special Paper 45, p. 75–105.

Murphy, D.C., van Staal, C., and Mortensen, J.K., 2008. Windy McKinley terrane, Stevenson Ridge area (115JK), western Yukon: composition and proposed correlations, with implications for mineral potential; *in* Yukon Exploration and Geology 2007, (ed.) D.S. Emond, L.R. Blackburn, R.P. Hill, and L.H. Weston, Yukon Geological Survey, p. 225–235.

Murphy, D.C., Mortensen, J.K., and van Staal, C., 2009. 'Windy-McKinley' terrane, western Yukon: new data bearing on its composition, age, correlation and paleotectonic settings; *in* Yukon Exploration and Geology 2008, (ed.) L.H. Weston, L.R. Blackburn, and L.L. Lewis; Yukon Geological Survey, p. 195–209.

North American Commission on Stratigraphic Nomenclature, 2005. North American stratigraphic code; American Association of Petroleum Geologists Bulletin, v. 89, no. 11, p. 1547–1591. https://doi.org/10.1306/07050504129

Nelson, J.L. and Gehrels, G.E., 2007. Detrital zircon geochronology and provenance of the southeastern Yukon-Tanana terrane; Canadian Journal of Earth Sciences, v. 44, p. 297–316. https://doi.org/10.1139/e06-105

Nelson, J.L., Colpron, M., Piercey, S.J., Dusel-Bacon, C., Murphy, D.C., and Roots, C.F., 2006. Paleozoic tectonic and metallogenic evolution of the pericratonic terranes in Yukon, northern British Columbia and eastern Alaska; *in* Paleozoic Evolution and Metallogeny of Pericratonic Terranes at the Ancient Pacific Margin of North America, Canadian and Alaskan Cordillera, (ed.) M. Colpron and J.L. Nelson; Geological Association of Canada, Special Paper 45, p. 323–360.

Nelson, J.L., Colpron, M., and Israel, S., 2013. The Cordillera of British Columbia, Yukon and Alaska: tectonics and metallogeny; *in* Tectonics, Metallogeny, and Discovery: The North American Cordillera and Similar Accretionary Settings, (ed.) M. Colpron, T. Bissig, B.G. Rusk, and J.H.F. Thompson; Society of Economic Geologists, Special Publication 17, p. 53–109.

Parsons, A.J., Ryan, J.J., Coleman, M., and van Staal, C.R., 2017a. The Slide Mountain ophiolite, Big Salmon Range, south-central Yukon: preliminary results from fieldwork; *in* Yukon Exploration and Geology 2016, (ed.) K.E. MacFarlane and L.H. Weston; Yukon Geological Survey, p. 181–196.

Parsons, A.J., Ryan, J.J., and Coleman, M., 2017b. Report of activities, 2017: Dunite Peak area, Big Salmon Range, south-central Yukon: GEM2 Cordillera Project; Geological Survey of Canada, Open File 8307, 10 p. https://doi.org/10.4095/305966

Parsons, A.J., Coleman, M.J., Ryan, J.J., Joyce, N.L., Gibson, H.D., and Larson, K.P., 2018. Structural evolution of a crustal-scale shear zone through a decreasing temperature regime: the Yukon River shear zone, Yukon-Tanana terrane, Northern Cordillera; Lithosphere, v. 10, no. 6, p. 760–782. https://doi.org/10.1130/L724.1

Parsons, A.J., Zagorevski, A., Ryan, J.J., McClelland, W.C., van Staal, C.R., Coleman, M.J., and Golding, M.L., 2019. Petrogenesis of the Dunite Peak ophiolite, south-central Yukon, and the distinction between upper-plate and lower-plate settings: a new hypothesis for the late Paleozoic–early Mesozoic tectonic evolution of the Northern Cordillera; Geological Society of America Bulletin, v. 131, no. 1–2, p. 274–298. https://doi.org/10.1130/B31964.1

Patchett, P.J. and Gehrels, G.E., 1998. Continental influence on Canadian Cordilleran terranes from Nd isotopic study, and significance for crustal growth processes; The Journal of Geology, v. 106, p. 269–280. https://doi.org/10.1086/516021

Pecha, M.E., Gehrels, G.E., McClelland, W.C., Giesler, D., White, C., and Yokelson, I., 2016. Detrital zircon U-Pb geochronology and Hf isotope geochemistry of the Yukon-Tanana terrane, Coast Mountains, southeast Alaska; Geosphere, v. 12, p. 1556–1574. https://doi.org/10.1130/GES01303.1

Peter, J.M., Layton-Matthews, D., Piercey, S., Bradshaw, G., Paradis, S., and Boulton, A., 2007. Volcanic-hosted massive sulphide deposits of the Finlayson Lake District, Yukon; *in* Mineral Deposits of Canada: a Synthesis of Major Deposit-Types, District Metallogeny, the Evolution of Geological Provinces, and Exploration Methods, (ed.) W.D. Goodfellow; Geological Association of Canada, Mineral Deposits Division, Special Publication 5, p. 471–508.

Petrie, M.B., Gilotti, J.A., McClelland, W.C., van Staal, C.R., and Isard, S.J., 2015. Geologic setting of Eclogite-facies assemblages in the St. Cyr klippe, Yukon-Tanana terrane, Yukon, Canada; Geoscience Canada, v. 42, p. 327–350. https://doi.org/10.12789/geocanj.2015.42.073

Piercey, S.J. and Colpron, M., 2009. Composition and provenance of the Snowcap assemblage, basement to the Yukon-Tanana terrane, northern Cordillera: implications for Cordilleran crustal growth; Geosphere, v. 5, no. 5, p. 439–464. https://doi.org/10.1130/GES00505.S3

Piercey, S.J., Nelson, J.L., Colpron, M., Dusel-Bacon, C., Simard, R.-L., and Roots, C.F., 2006. Paleozoic magmatism and crustal recycling along the ancient Pacific margin of North America, northern Cordillera; *in* Paleozoic Evolution and Metallogeny of Pericratonic Terranes at the Ancient Pacific Margin of North America, Canadian and Alaskan Cordillera, (ed.) M. Colpron and J.L. Nelson; Geological Association of Canada, Special Paper 45, p. 281–322.

Roots, C.F., Nelson, J.L., Simard, R.-L., and Harms, T.A., 2006. Continental fragments, mid-Paleozoic arcs and overlapping late Paleozoic arc and Triassic sedimentary strata in the Yukon-Tanana terrane of northern British Columbia and southern Yukon; *in* Paleozoic Evolution and Metallogeny of Pericratonic Terranes at the Ancient Pacific Margin of North America, Canadian and Alaskan Cordillera, (ed.) M. Colpron and J.L. Nelson; Geological Association of Canada, Special Paper 45, p. 153–177.

Ruks, T.W., Piercey, S.J., Ryan, J.J., Villeneuve, M.E., and Creaser, R.A., 2006. Mid- to Late Paleozoic K-feldspar augen granitoids of the Yukon-Tanana terrane, Yukon: implications for crustal growth and tectonic evolution of the northern Cordillera; Geological Society of America Bulletin, v. 118, p. 1212–1231. https://doi.org/10.1130/B25854.1

Ryan, J.J., 2014. Jurassic structural and tectonic architecture of Yukon Tanana terrane in west central Yukon; *in* Program with Abstracts; 2014 Geological Societey of America Annual Meeting, Vancouver, British Columbia, October 19–22, 2014, Paper No. 240-12.

Ryan, J.J., Colpron, M., and Hayward, N., 2010. Geology, southwestern McQuesten and parts of northern Carmacks, Yukon: Geological Survey of Canada, Canadian Geoscience Map 7 (preliminary edition), scale 1:125 000. https://doi.org/10.4095/287154

Ryan, J.J., Zagorevski, A., Williams, S.P., Roots, C., Ciolkiewicz, W., Hayward, N., and Chapman, J.B., 2013a. Geology, Stevenson Ridge (northeast part), Yukon; Geological Survey of Canada, Canadian Geoscience Map 116 (2nd preliminary edition), scale 1:100 000. https://doi.org/10.4095/292407

Ryan, J.J., Zagorevski, A., Williams, S.P., Roots, C., Ciolkiewicz, W., Hayward, N., and Chapman, J.B., 2013b. Geology, Stevenson Ridge (northwest part), Yukon; Geological Survey of Canada, Canadian Geoscience Map 117 (2nd preliminary edition), scale 1:100 000. https://doi.org/10.4095/292408

Ryan, J.J., Zagorevski, A., Roots, C.F., and Joyce, N., 2014. Paleozoic tectonostratigraphy of the northern Stevenson Ridge area, Yukon; Geological Survey of Canada, Current Research 2014-4, 13 p. https://doi.org/10.4095/293924

Ryan, J.J., Nelson, J.L., and van Staal, C., 2015. Fieldwork in the Sylvester allochthon, Cassiar Mountains, British Columbia: investigations of the Rapid River tectonite and the Slide Mountain terrane; *in* Geological Fieldwork 2014; British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Paper 2015-1, p. 113–128.

Ryan, J.J., Westberg, E.E., Williams, S.P., and Chapman, J.B., 2016. Geology, Mount Nansen–Nisling River area, Yukon; Geological Survey of Canada, Canadian Geoscience Map 292 (preliminary edition), scale 1:100 000. https://doi.org/10.4095/298835

Ryan, J.J., Zagorevski, A., Joyce, N.L., Staples, R.D., Jones, J.V., and Gibson, H.D., 2017. Mid-Cretaceous core complexes in the northern Cordillera: exposing the parautochthon through a thin flap of allochthonous Yukon-Tanana terrane in western Yukon; Geological Society of America, Program with Abstracts, v. 49, no. 6. https://doi.org/10.1130/abs/2017AM-298292

Ryan, J.J., Israel, S., Williams, S.P., Parsons, A.J., and Hayward, N., 2018a. Bedrock geology, Klaza River area, Yukon; Geological Survey of Canada, Canadian Geoscience Map 376, scale 1:100 000. https://doi.org/10.4095/311301

Ryan, J.J., Zagorevski, A., Joyce, N.L., Staples, R.D., and Gibson, H.D., 2018b. Mid-Cretaceous core complexes in the northern Cordillera of Yukon: deciphering their elusive boundaries; *in* Program with Abstracts; Resources for Future Generations, June 16–21, 2018, Vancouver, British Columbia, abstract no. 1959.

Sack, P.J., Colpron, M., Crowley, J.L., Ryan, J.J., Allan, M.M., Beranek, L.P. and Joyce, N.L., 2020. Atlas of Late Triassic to Jurassic plutons in the Intermontane terranes of Yukon; Yukon Geological Survey, Open File 2020-1, 365 p.

Staples, R.D., 2014. Diachronous deformation, metamorphism and exhumation in the northern Canadian Cordillera: revealed from pressure-temperature-time-deformation paths of former mid-crustal rocks; Ph.D. thesis, Simon Fraser University, Vancouver, British Columbia, 229 p.

Staples, R.D., Gibson, H.D., Berman, R.G., Ryan, J.J., and Colpron, M., 2013. A window into the Early to mid-Cretaceous infrastructure of the Yukon-Tanana terrane recorded in multi-stage garnet of west-central Yukon, Canada; Journal of Metamorphic Geology, v. 31, p. 729–753. https://doi.org/10.1111/jmg.12042

Staples, R., Gibson, H.D., Colpron, M., and Ryan, J.J., 2016. An orogenic wedge model for diachronous deformation, metamorphism, and exhumation in the hinterland of the northern Canadian Cordillera; Lithosphere, v. 8, no. 2, p. 165–184. https://doi.org/10.1130/L472.1

Tempelman-Kluit, D.J., 1974. Reconnaissance geology of Aishihik Lake, Snag and part of Stewart River map-areas, west-central Yukon Territory; Geological Survey of Canada, Paper 73-14, 93 p. https://doi.org/10.4095/102542

Tempelman-Kluit, D.J., 1979. Transported cataclasite, ophiolite and granodiorite in Yukon: evidence of arc-continent collision; Geological Survey of Canada, Paper 79-14, 27 p. https://doi.org/10.4095/105928

Topham, M.J., 2015. Emplacement depth and porphyry copper-gold potential of Late Triassic to Early Jurassic granitoids in Yukon; B.Sc. thesis, University of British Columbia, Vancouver, British Columbia, 66 p.

van Staal, C.R., Zagorevski, A., McClelland, W.C., Escayola, M., Ryan, J.J., Parsons, A.J., and Proenza, J.A., 2018. Age and setting of Permian Slide Mountain terrane ophiolitic ultramafic-mafic complexes in the Yukon: implications for late Paleozoic-early Mesozoic tectonic models in the northern Canadian Cordillera; Tectonophysics, v. 744, p. 458–483. https://doi.org/10.1016/j.tecto.2018.07.008

Vermeesch, P., 2013. Multi-sample comparison of detrital age distributions; Chemical Geology, v. 341, p. 140–146. https://doi.org/10.1016/j.chemgeo.2013.01.010

Yukon Geological Survey, 2019. Yukon Digital Bedrock Geology; Yukon Geological Survey, <http://www.geology.gov.yk.ca/update_yukon_bedrock_geology_map.html> [accessed: November 1, 2019]

Zagorevski, A., Ryan, J., Roots, C., and Hayward, N., 2012. Ultramafic rock occurrences in the Dawson Range and their implications for the crustal structure of Yukon-Tanana terrane, Yukon (parts of 115I, J and K); Geological Survey of Canada, Open File 7105, 1 sheet. https://doi.org/10.4095/290992