Stratigraphy of the Faro Peak formation, central Yukon: New field observations of Jurassic synorogenic sedimentation along the Yukon-Tanana–Slide Mountain terrane boundary

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Abstract

The Faro Peak formation is a Lower Jurassic(?) unit assigned to the Yukon-Tanana terrane in the southern Tay River map area (NTS 105K). A two-year project was initiated in 2018 to investigate the Faro Peak formation and constrain its stratigraphy, age, and significance to Cordilleran tectonic evolution. The exposed base of the Faro Peak formation includes argillite and organized to disorganized sandstone units that crop out southwest of the Yukon-Tanana–Slide Mountain terrane boundary near Faro. Lower Faro Peak formation units have mafic-intermediate volcanic provenance and were deposited by concentrated density flows or turbidity currents. The upper Faro Peak formation contains massive, disorganized conglomerate and sandstone units that were sourced from the Yukon-Tanana and Slide Mountain terranes and deposited by non-turbulent debris or density flows. The Faro Peak formation is likely the remnant of a synorogenic basin that formed as a result of Intermontane belt exhumation in central Yukon.

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Introduction

Late Triassic–Early Jurassic plate convergence and collision along the northern Cordilleran margin resulted in the exhumation of the Intermontane terranes—Yukon-Tanana, Slide Mountain, Stikinia, Quesnellia, and Cache Creek—and subsequent generation of overlapping synorogenic basins (Mihalynuk et *al*., 1994; Johnston et *al*., 1996; Evenchick et *al*., 2007; Knight et *al*., 2013; Nelson et *al*., 2013). In central Yukon, synorogenic Lower to Middle Jurassic strata assigned to the Laberge Group record the timing and spatial extent of Intermontane belt exhumation and represent a regional basin known as the Whitehorse trough (Fig. 1; *e.g.*, Tempelman-Kluit, 1984; Dickie and Hein, 1995; Hart et *al*., 1995; Colpron et *al*., 2015; van Drecht and Beranek, 2018). Colpron et *al*. (2015) recently proposed that Laberge Group deposition was coincident with the onset of foreland basin subsidence in southern Canadian Rockies (see Fernie Formation in Fig. 1), suggesting that the Whitehorse trough and related synorogenic basins in Yukon and northern British Columbia are critical to understanding the early growth of the Cordilleran orogen.

Isolated occurrences of Lower Jurassic(?) strata known informally as the Faro Peak formation crop out near the Yukon-Tanana–Slide Mountain terrane boundary in the Faro region of central Yukon and are presumably correlative with synorogenic rock units of the Whitehorse trough (Fig. 1; e.g., Pigage, 2004; Colpron et *al*., 2015). A two-year project was initiated to test this hypothesis and constrain the role of Intermontane belt tectonics on Faro Peak formation deposition. In this article, we summarize the field geology of Faro Peak formation outcrops visited during summer 2018. These field observations will be integrated with future detrital zircon U-Pb-Hf studies to confirm the depositional age and provenance of Faro Peak formation rock units and determine the spatial extent of Jurassic exhumation and synorogenic sedimentation in the northern Cordillera.

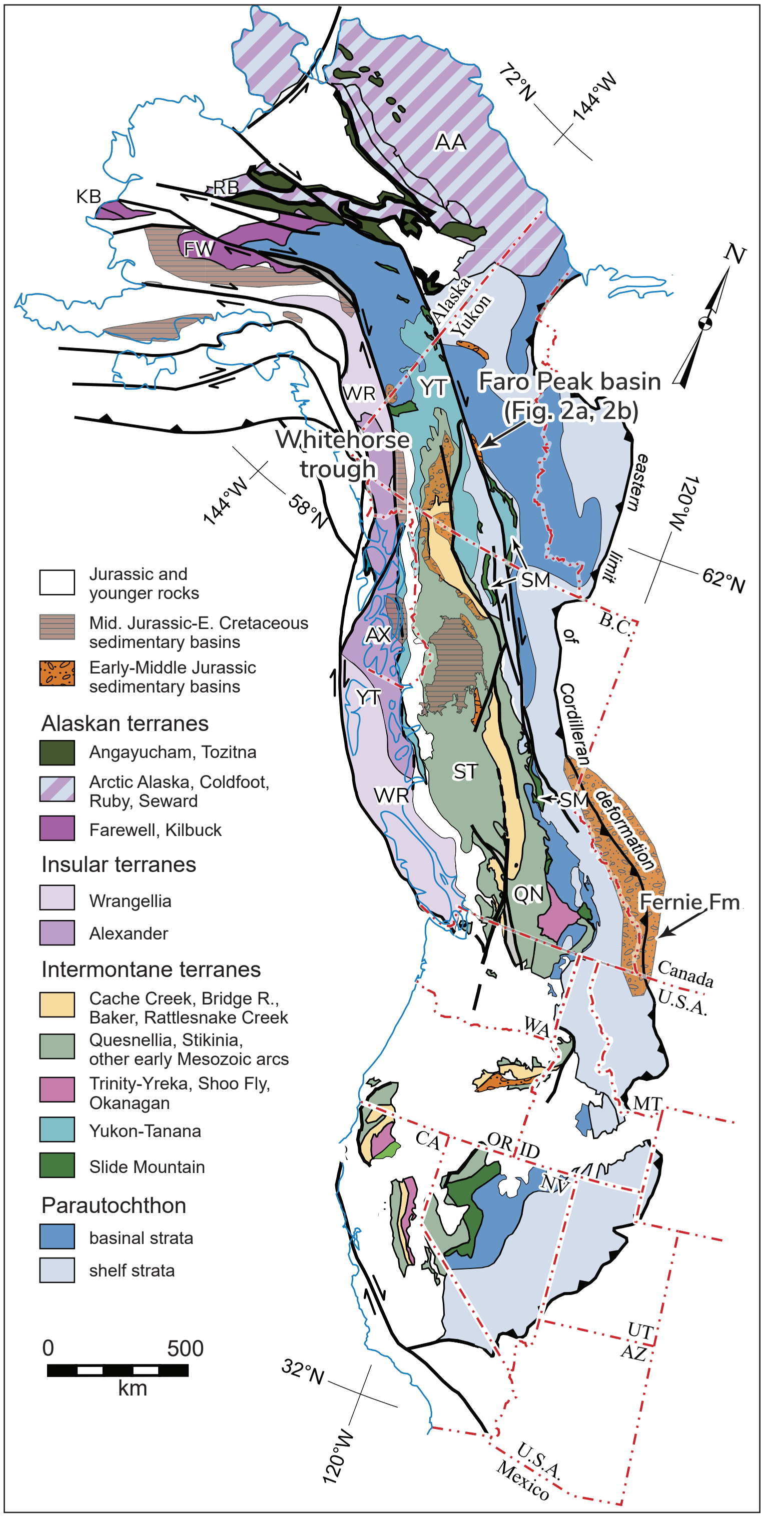

Figure 1. *Paleozoic to early Mesozoic terrane map of the North American Cordillera and associated Jurassic basins modified from Colpron et al. (2015). Terrane abbreviations: AA–Arctic Alaska; AX–Alexander; FW–Farewell; KB–Kilbuck; QN–Quesnellia; RB–Ruby; SM–Slide Mountain; ST–Stikinia; WR–Wrangellia; YT–Yukon-Tanana.*

Geological Background

The Faro townsite is located along the eastern edge of the Intermontane belt in the southern Tay River map area (NTS 105K). In this region, the Intermontane terranes are juxtaposed against North American continental margin strata of Selwyn basin along the Inconnu thrust to the northeast and Cassiar terrane across the Tintina fault to the southwest (Fig. 2a; Pigage, 2004). The Yukon-Tanana and Slide Mountain terranes are separated by the northwest-trending Vangorda fault in the Faro region (Fig. 2b). Pigage (2004) concluded that the Vangorda fault had normal displacement, whereas Colpron et *al.* (2015) interpreted a strike-slip history based on its correlation with the Jules Creek fault (Murphy et *al.*, 2006) in southeastern Yukon.

The Faro Peak formation sits unconformably on quartzite, schist, and other metasedimentary rock units of the pre-Late Devonian Snowcap assemblage, which forms the exposed base of the Yukon-Tanana terrane in central Yukon (Fig. 2b; Colpron et *al.*, 2006). Rocks that comprise the Faro Peak formation were first described by Tempelman-Kluit (1972, 1979) and informally named by Pigage (2004). The Faro Peak formation is generally divided into two members (e.g., Pigage, 2004): a lower member of interbedded basalt, argillite, chert, greywacke, limestone, and conglomerate, and an upper member of massive, polymictic conglomerate with pebble to boulder-sized clasts that are dominated by local Yukon-Tanana and Slide Mountain rocks. The Faro Peak formation has an erosional top and maximum thickness estimates range from >560 m (Pigage, 2004) to >840 m (Tempelman-Kluit, 1979).

Pigage (2004) assigned a Late Triassic depositional age to the Faro Peak formation based on Carnian to Rhaetian conodont elements retrieved from limestone clasts and beds in the lower and upper members. Beranek (2009) collected samples of upper member sandstone at two fossil localities and reported 220–190 Ma detrital zircon populations that instead support an Early Jurassic maximum depositional age for the upper Faro Peak formation. Analogous detrital zircon populations have been recognized in Laberge Group strata of the Whitehorse trough (Colpron et *al.*, 2015;

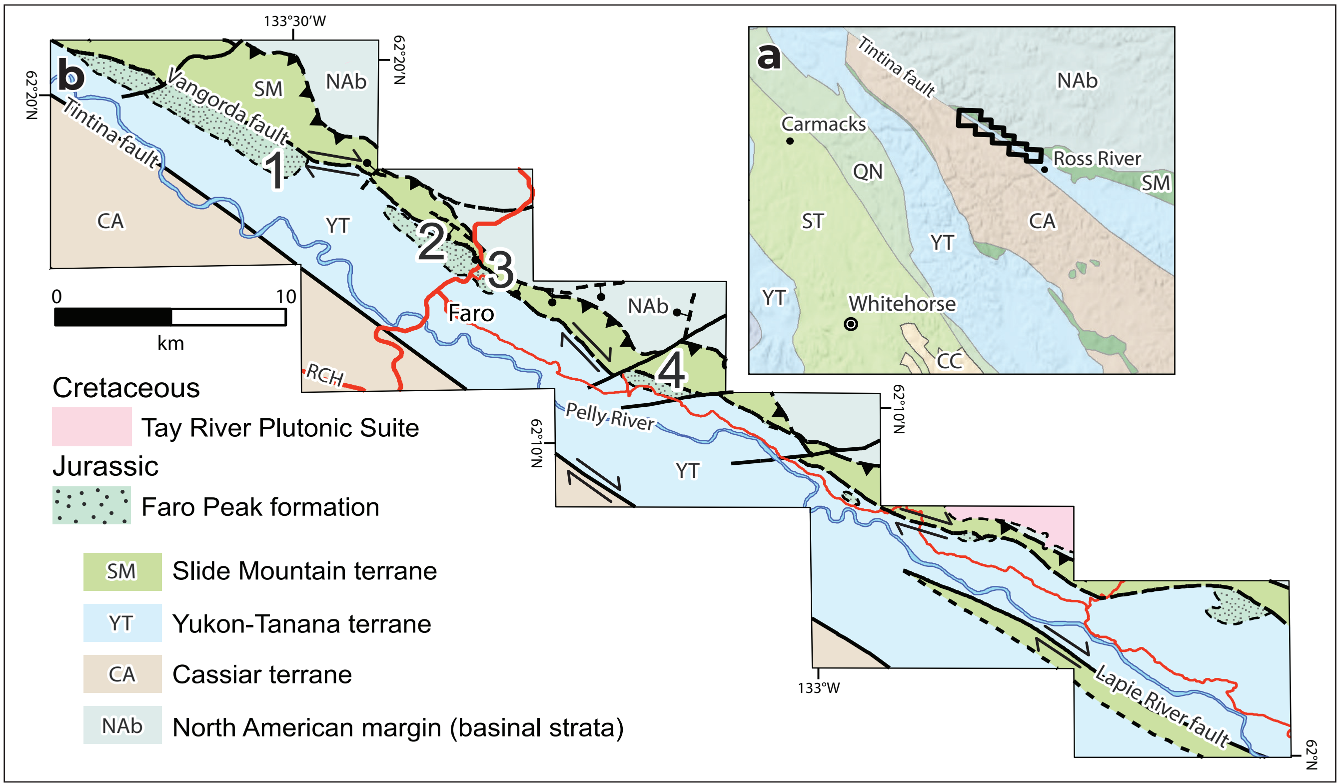

***Figure 2. (a)** Terrane map of central Yukon modified from Yukon Geological Survey (2018). **(b)** Simplified bedrock geology of the southern Tay River map area modified from Pigage (2004). The numbers 1–4 denote the field localities described in this article.*

van Drecht and Beranek, 2017), suggesting that the Faro Peak formation comprises the remnants of a much larger synorogenic basin system related to Jurassic exhumation across central and southern Yukon.

2018 Field Studies

Locality 1–Faro Peak

Faro Peak and adjacent alpine ridges ~15 km northwest of Faro likely represent the thickest exposures of the Faro Peak formation (locality 1 in Fig. 2b). Lower member rock units observed during summer 2018 crop out along the northeastern flank of Faro Peak (Fig. 3), immediately southwest of the Vangorda fault, and comprise poorly exposed sections of argillite, siltstone, and fine-grained micaceous lithic arenite (Fig. 4a). Pigage (2004) reported that potentially correlative basalt and fine-grained siliciclastic rocks are exposed in the lower Faro Peak formation south and west of Rose Mountain, ~3 km northwest of Faro Peak (Fig. 3). If correct, these lower Faro Peak formation rocks may be coeval with Permian basalt and chert northeast of the Vangorda fault (Campbell Range formation) and represent an overlap assemblage that covers the Yukon-Tanana and Slide Mountain terranes. However, it is possible that these basalt and siliciclastic rock units are instead part of the Slide Mountain terrane and not Faro Peak formation, which may call for a reassessment of the Vangorda fault and location of the Yukon-Tanana–Slide Mountain terrane boundary in this region.

The upper member of the Faro Peak formation near Faro Peak mostly consists of brown weathering, granule to cobble, matrix to clast-supported, polymictic conglomerate intercalated with feldspathic lithic to lithic arenite (Fig. 4b,c). The gravelly and sandy lithofacies are generally massive and lack sedimentary structures, which make stratigraphic younging and bedding determinations difficult. Clast types in the gravelly lithofacies are dominated by quartzite and mica schist with subordinate populations of limestone, grey

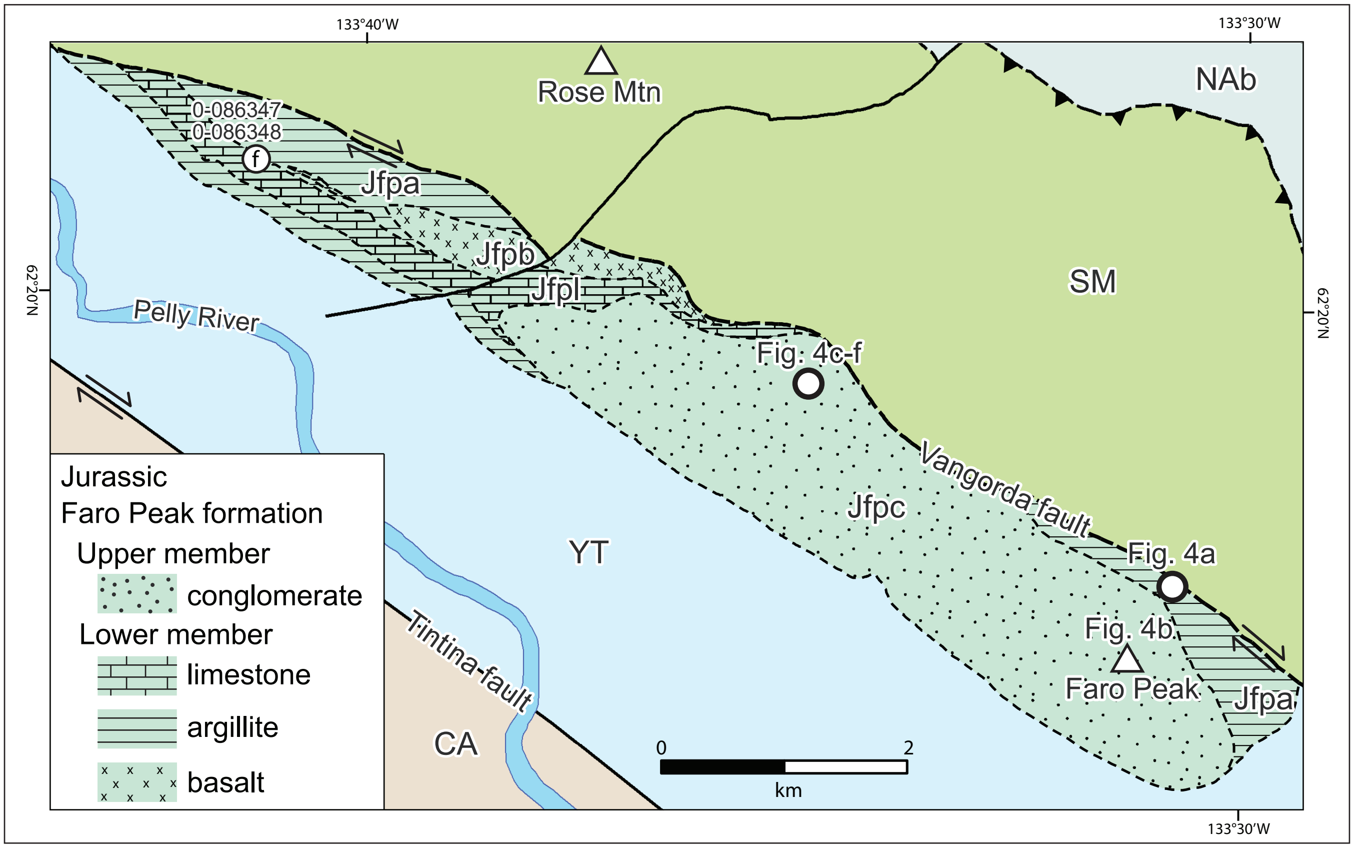

Figure 3. *Simplified bedrock geology of the Faro Peak area (locality 1) modified from Pigage (2004). Faro Peak formation units: Jfpc–upper member conglomerate and sandstone; Jfpl–lower member limestone; Jfpa–lower member argillite, chert, siltstone, and sandstone; Jfpb–lower member basalt. Terrane abbreviations as in Fig. 2b.*

Figure 4. Field photographs of the Faro Peak area (locality 1). ***(a)*** Lower member argillite, siltstone, and fine-grained micaceous lithic arenite along northeastern flank of Faro Peak; ***(b)*** upper member lithic sandstone at Faro Peak; ***(c)*** upper member clast-supported polymictic conglomerate; ***(d)*** upper member grey chert clast; ***(e)*** upper member quartz-feldspar porphyry clast; and ***(f)*** upper member felsic intrusive clast. Scale bar has 1 cm solid divisions.

to green to pink chert (Fig. 4d), argillite, and aphanitic to porphyritic basalt. Vein quartz, quartz-feldspar porphyry (Fig. 4e), and felsic intrusive rocks (Fig. 4f) occur as minor clast components.

Abundant quartzite and schist rock fragments in the Faro Peak area successions imply provenance from the underlying Snowcap assemblage, which suggests that gravel and coarse-grained sand deposition were coincident with the exhumation of Yukon-Tanana basement. Subordinate basalt, chert, and argillite clasts are furthermore consistent with derivation from the adjacent Campbell Range formation and older rock units of the Slide Mountain terrane near Rose Mountain. Limestone and intermediate-felsic intrusive rocks have uncertain provenance, but our working hypothesis calls for these clasts to have origins from Yukon-Tanana and/or Stikinia rock assemblages that similarly flank the Whitehorse trough in the Carmacks area of central Yukon (*e.g.*, Colpron et *al.*, 2015).

Locality 2–Whiskey Mountain

The Faro Peak formation underlies the region ~3 km north of Faro, including Whiskey Mountain to the west of the Faro Mine Access Road (locality 2 in Fig. 2b; Figs. 5 and 6a). Some of the oldest lower member strata in this region, <500 m south of the Vangorda fault, consist of grey to green, fine to medium-grained, feldspathic lithic arenite (Fig. 6b). Preliminary petrographic observations show evidence of angular plagioclase crystals and volcanic rock fragments that

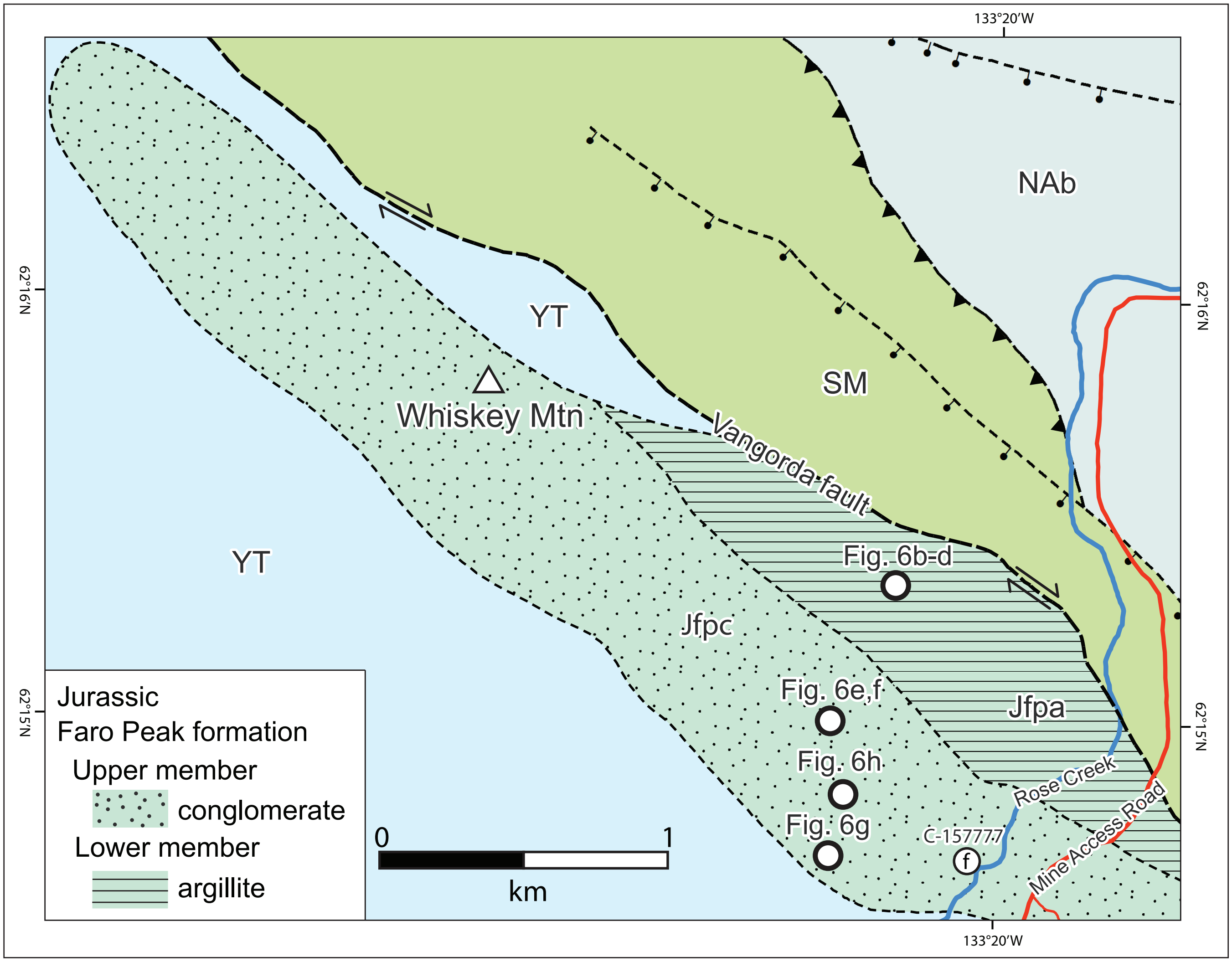

Figure 5. *Simplified bedrock geology of the Whiskey Mountain area (locality 2) modified from Pigage (2004). Faro Peak formation units: Jfpc–upper member conglomerate and sandstone; Jfpa–lower member argillite, siltstone, and sandstone. Terrane abbreviations as in Fig. 2b.*

suggest a proximal igneous source (Fig. 6c). Mud–sand couplets affected by isoclinal folding (Fig. 6d), interpreted in the field as convolute bedding, overlie these strata. Massive, tabular beds of coarse to very coarse grained feldspathic arenite units occur stratigraphically above the convolute beds.

The depositional contact between the lower and upper members is not well exposed in the Whiskey Mountain area. Near the cliffs along Rose Creek, immediately west of the Faro Mine Access Road, this contact may be evident where interbeds of argillite and sandstone of the lower member are overlain by sandstone and conglomerate of the upper member. More broadly, our field observations indicate that interfingered relationships may occur between some lower and upper member rock units. At other Whiskey Mountain locations, upper member rock units show both lateral and vertical fining trends, which may also indicate that sandstone layers form erosional channels within conglomerate units rather than the two having conformable, interbedded relationships. Graded bedding and channelized sandstone features are rarely observed because of vegetation and massive nature of the outcrop, but evident within some of the lower parts of the upper member at Whiskey Mountain (Fig. 6e,f). Regionally, upper member conglomerate

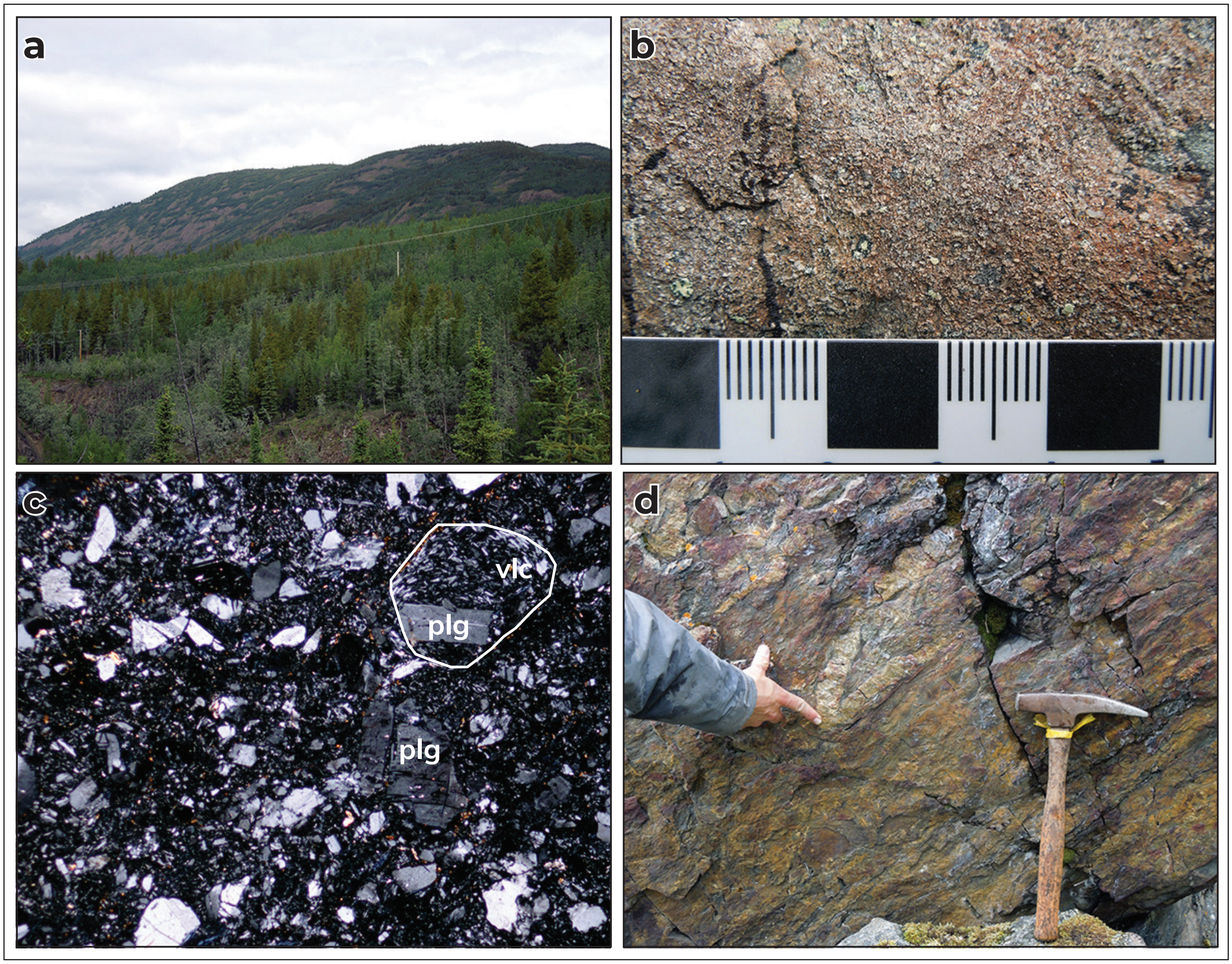

Figure 6. *Field photographs of the Whiskey Mountain area (locality 2).* ***(a)*** *North-directed view of Whiskey Mountain area and Faro Peak formation exposures from Faro townsite;* ***(b)*** *lower member feldspathic lithic arenite;* ***(c)*** *photomicrograph of lower member feldspathic lithic arenite showing angular plagioclase (plag), quartz, and volcanic lithic fragments (vlc) at 4x magnification;* ***(d)*** *isoclinal fold in convoluted beds of lower member;* ***(e)*** *through* ***(h)*** *on next page.*

units are recognized to directly overlie Snowcap assemblage basement (Pigage, 2004), suggesting that the lower member was completely removed by erosion in some areas.

Upper member units in the Whiskey Mountain area generally consist of massive, brown weathering, granule to boulder, clast-supported, polymictic conglomerate and interbedded micaceous feldspathic lithic arenite (Fig. 6g). The dominant clast types are micaceous quartzite, mica schist, chert, and limestone with Carnian conodont elements (C-157777; Pigage, 2004). Some of the micaceous quartzite and mica schist clasts are up to 50 cm in size, suggesting local derivation from the underlying Snowcap assemblage. Other clast types include basalt, argillite, vein quartz, quartz-feldspar porphyry, hornblende granodiorite, and augite-phyric basalt (Fig. 6h). Upper member sandstone adjacent to the Carnian fossil collection at Whiskey Mountain correspondingly shows a mixture of detrital zircon U-Pb ages that indicate recycled Precambrian contributions from Snowcap assemblage quartzite and schist and Late Triassic–Early Jurassic contributions presumably from igneous sources (Colpron et *al.*, 2015).

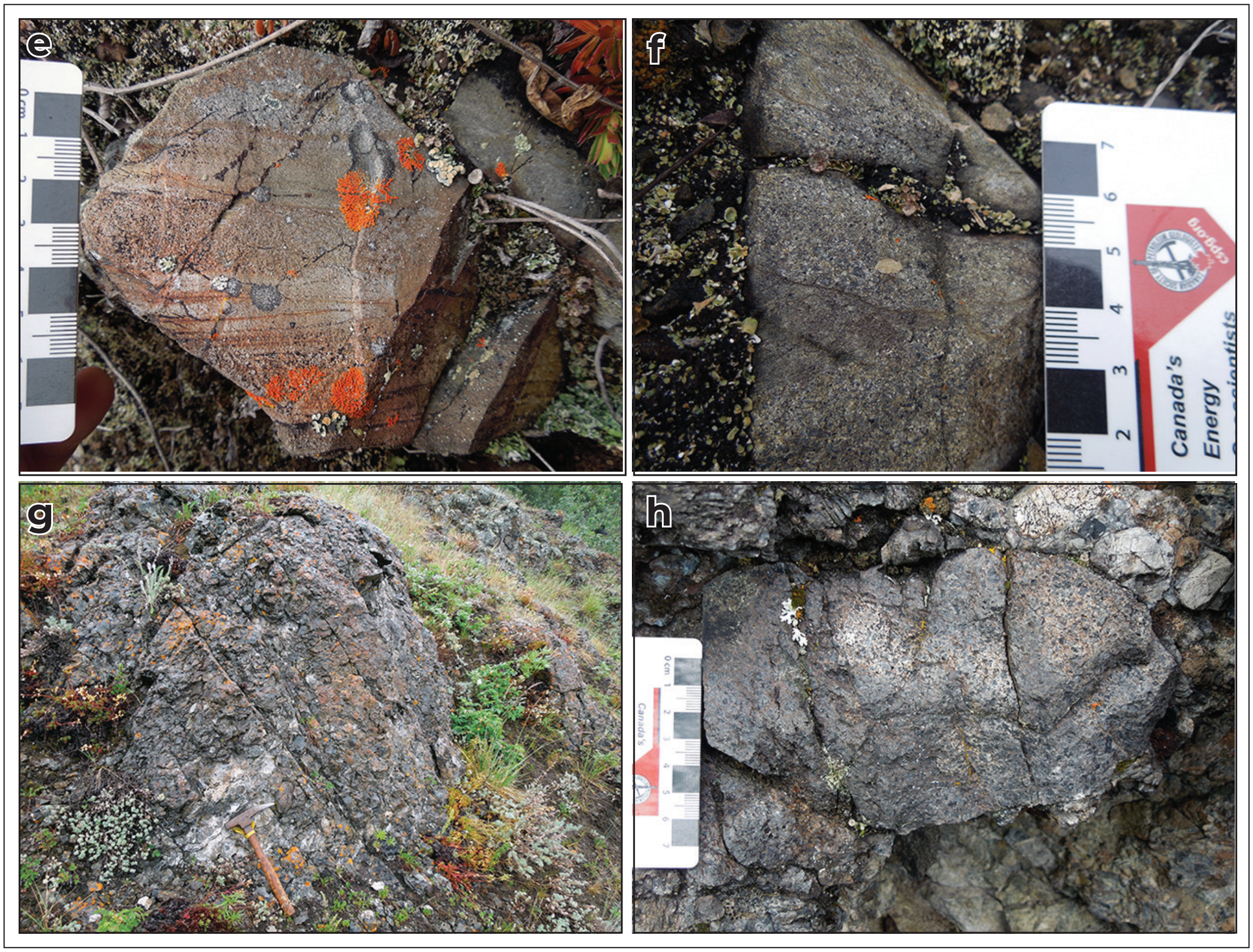

***Figure 6** continued. **(e)** graded bedding in upper member sandstone; **(f)** channelized sandstone lens in upper member conglomerate; **(g)** upper member clast-supported conglomerate; and **(h)** upper member augite-phyric basalt clast.*

Locality 3–Repeater Hill

Lower and upper member exposures of the Faro Peak formation crop out along the access road and flanks of the informally named Repeater Hill (site of the NorthwesTel repeater), ~2.5 km northeast of the Faro townsite (locality 3 in Fig. 2b; Fig. 7). The contact between lower and upper members is observed along the southeastern flank of Repeater Hill where dark grey, fine to medium-grained micaceous sandstone interfingers with, or pinches out, into matrix-supported conglomerate with pebble-sized clasts of schist, chert, argillite, micaceous quartzite, and limestone (Fig. 8a–c). This section reappears on the west side of Repeater Hill and may be analogous to the interfingered relationships observed in the adjacent Whiskey Mountain area. Grey limestone to silty limestone subcrop exposures at the top of Repeater Hill (Fig. 8d) contain early Carnian conodont elements (C-304121; Pigage, 2004) and have unclear contact relationships with upper member conglomerate.

Upper member rock units that are exposed along Repeater Road are dominated by massive, brown to grey weathering, matrix to clast-supported, pebble to cobble conglomerate (Fig. 8e) and lithic feldspathic arenite (Fig. 8f). Most clast types along the road consist of quartzite, mica schist (Fig. 8g), limestone, and chert; clasts of quartz-feldspar porphyry and other igneous rocks were observed along southwestern flank of Repeater Hill.

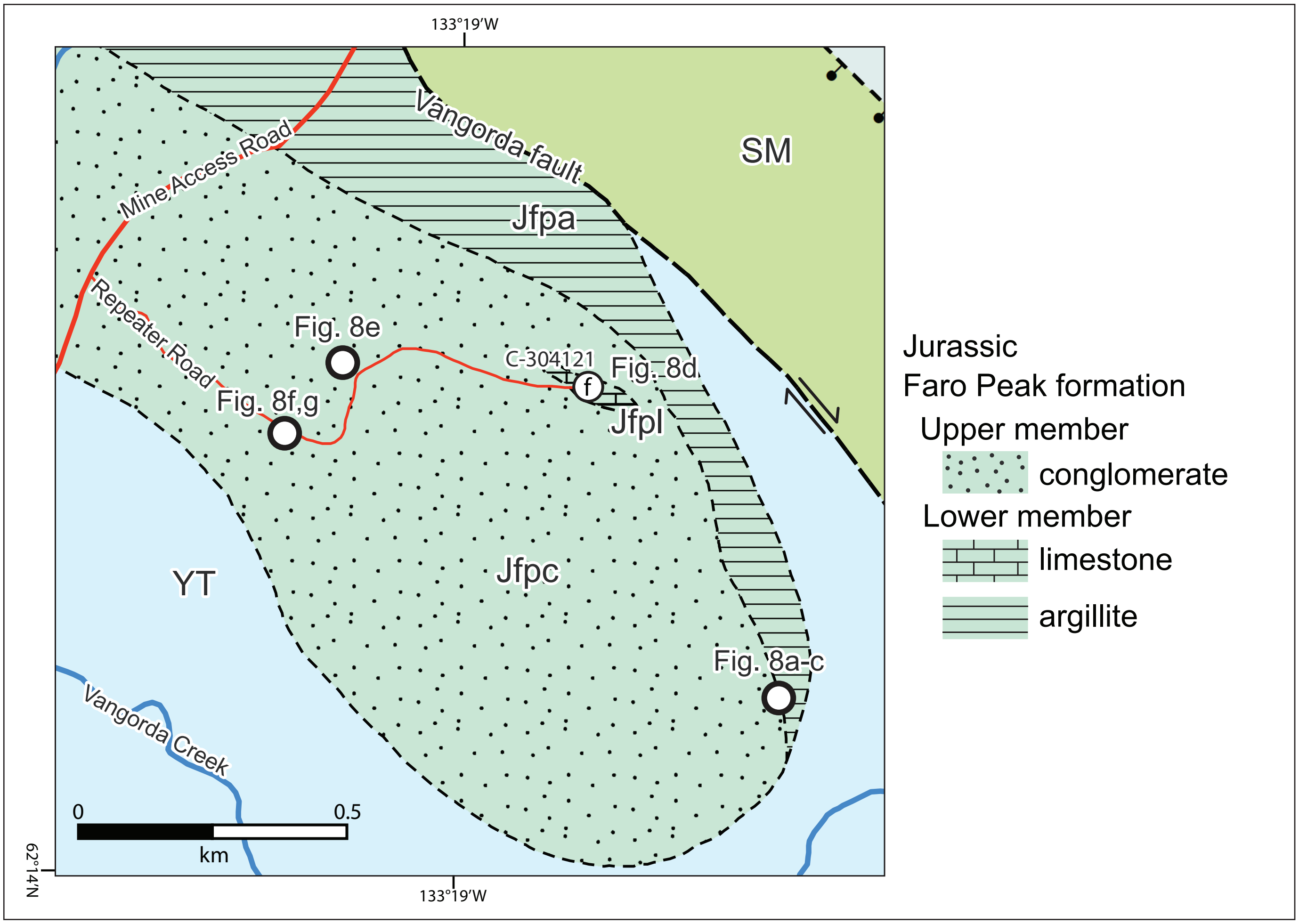

Figure 7. *Simplified bedrock geology map of the Repeater Hill area (locality 3) modified from Pigage (2004). Faro Peak formation units: Jfpc–upper member conglomerate and sandstone; Jfpl–lower member limestone; Jfpa–lower member argillite, chert, siltstone, and sandstone. Terrane abbreviations as in Fig. 2b.*

Figure 8. *Field photographs Repeater Hill area (locality 3).* ***(a)*** *Contact between lower and upper members along southeastern flank of Repeater Hill;* ***(b)*** *upper member basal conglomerate;* ***(c)*** *top of lower member argillite unit;* ***(d)*** *lower member limestone to silty limestone near repeater;* ***(e)*** *upper member matrix to clast-supported conglomerate on Repeater Road;* ***(f)*** *and* ***(g)*** *on next page.*

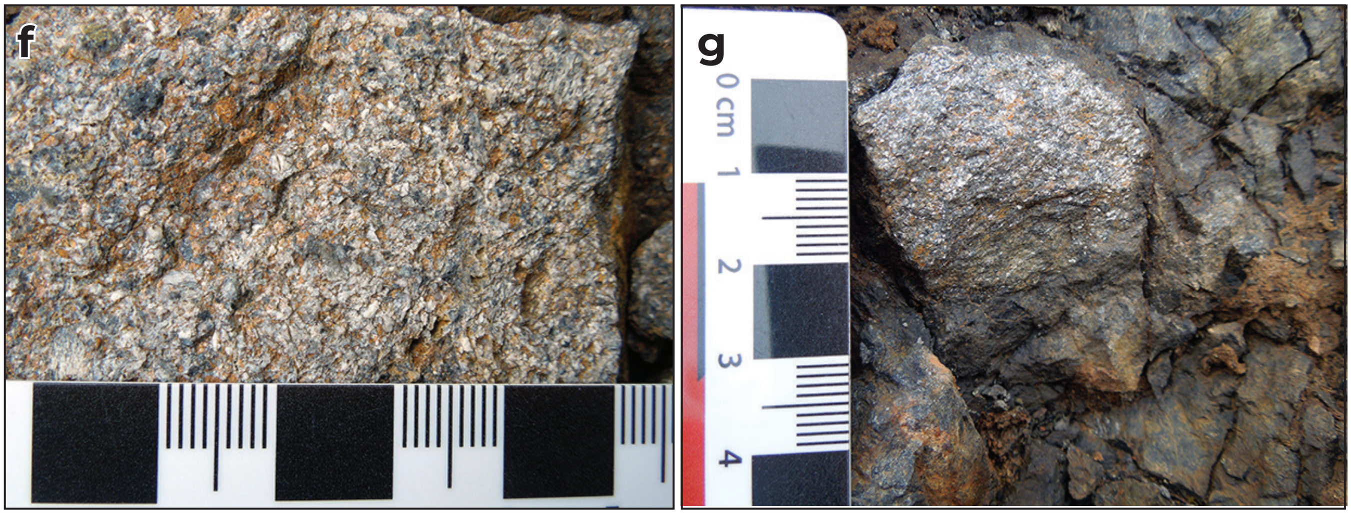

Figure 8 *continued. **(f)** upper member lithic feldspathic sandstone; and **(g)** upper member mica schist clast.*

Locality 4–Blind Creek Road and Dena Cho Trail

Upper member strata were accessed by foot traverse along the Blind Creek Road and western end of the Deno Cho Trail ~11 km east of Faro (locality 4 in Fig. 2b; Fig. 9). Near Blind Creek, Faro Peak formation outcrops mostly consist of massive, matrix to clast-supported, granule to pebble conglomerate units with quartzite, schist, chert, limestone, and minor felsic igneous and basalt clasts that resemble other upper member exposures across the southern Tay River map area (Fig. 10a–c). Sandstone matrix from a Blind Creek conglomerate layer with late Carnian limestone clasts (C-103825; Pigage, 2004) yielded Late Triassic–Early Jurassic and older detrital zircon populations that suggest mixed Mesozoic igneous and Snowcap assemblage provenance (Colpron et al., 2015).

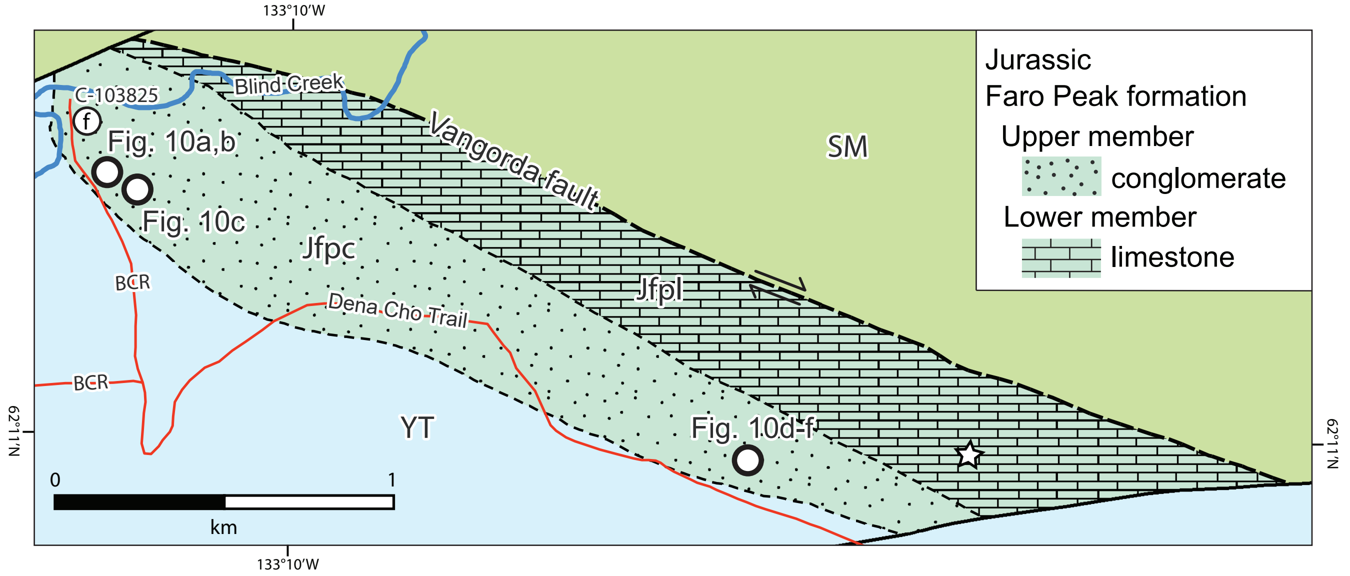

Figure 9. *Simplified bedrock geology of the Blind Creek Road and western Dena Cho Trail areas (locality 4). Star denotes location of chloritized basalt outcrop with possible Slide Mountain terrane (Campbell Range formation) affinities. Faro Peak formation units: Jfpc–upper member conglomerate and sandstone; Jfpl–lower member limestone. BCR–Blind Creek Road. Terrane abbreviations as in Fig. 2b.*

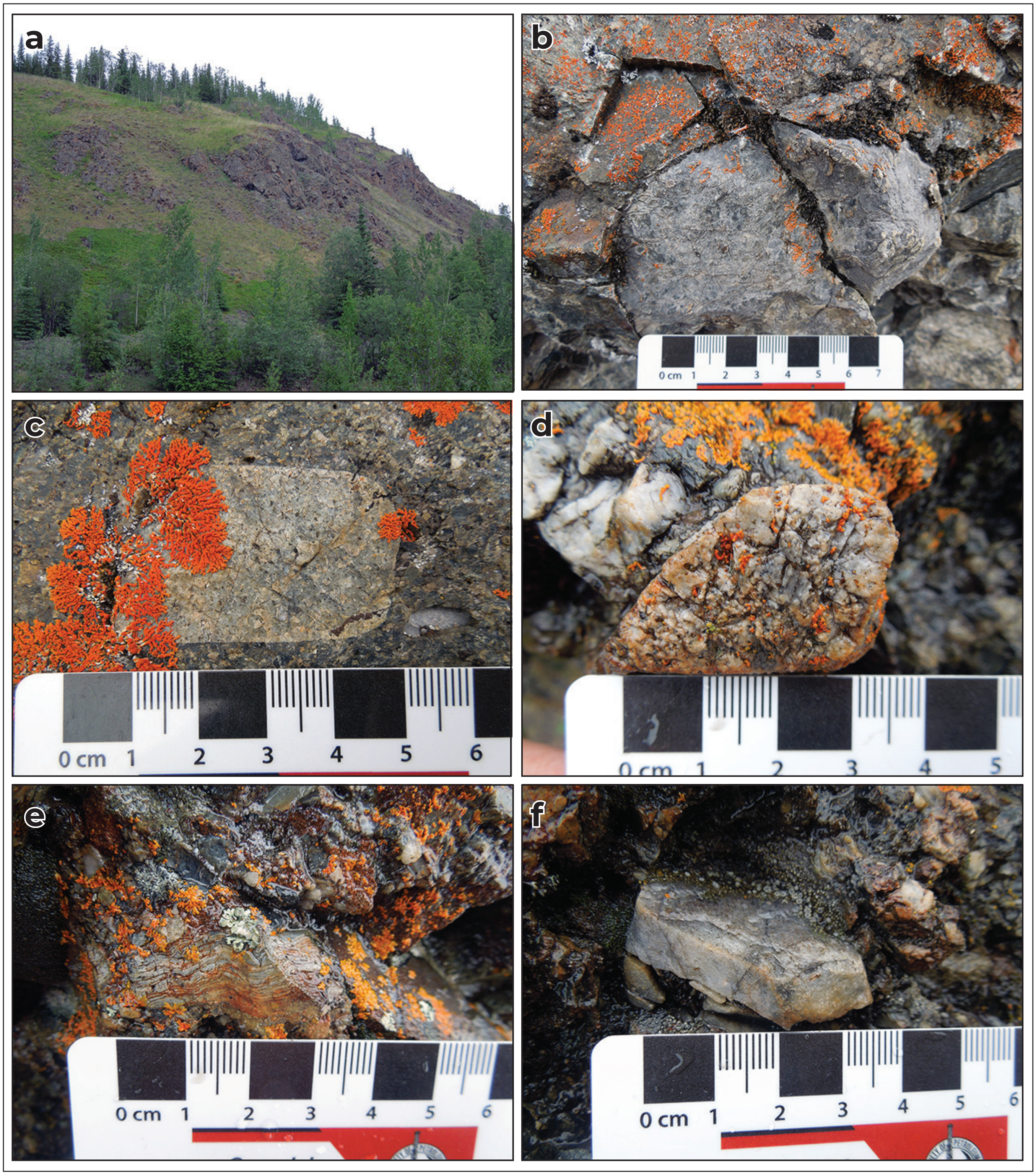

Figure 10. *Field photographs of Blind Creek Road and western Dena Cho Trail areas (locality 4).* ***(a)*** *Northeast-directed view of upper member conglomerate outcrops east of Blind Creek;* ***(b)*** *upper member limestone clast;* ***(c)*** *upper member quartz porphyry clast;* ***(d)*** *upper member felsic intrusive clast;* ***(e)*** *upper member bedded chert clast; and* ***(f)*** *upper member quartzite clast.*

Rounded and discontinuous exposures of the upper member occur along the Dena Cho Trail to the southeast of Blind Creek (Fig. 9) and generally comprise pebble to cobble conglomerate with interlayers of coarse-grained to pebbly sandstone. Clasts consist of quartzite, bedded chert, limestone, and schist with minor amounts of quartz-feldspar porphyry and felsic intrusive rocks (Fig. 10d–f). At one location along the Dena Cho Trail, a brown weathering outcrop assigned to the Faro Peak formation consists of chloritized basalt that resembles the adjacent Campbell Range formation (see Fig. 9). This outcrop is either an unmapped basalt unit within the Faro Peak formation or represents an outlier or fault sliver of Slide Mountain terrane.

Preliminary Conclusions and Future Research

The Faro Peak formation is characterized by an upper member of massive, disorganized conglomerate and sandstone units and a lower member of argillite, siltstone, and sandstone units that contain massive to graded to convolute bedding features. The depositional setting and emplacement mechanisms of these Faro Peak formation facies are the topics of current research and will continue to be a focus during the second field season in summer 2019. Tempelman-Kluit (1972) interpreted the massive and coarse-grained nature of the upper member conglomerate to indicate deposition adjacent to a fault scarp complex, presumably linked to displacement along the Vangorda fault or its predecessor. The lower member contains feldspathic and volcanic lithic sandstone strata, which further implies proximity to a mafic-intermediate igneous source. Our working hypothesis calls for massive clast to matrix-supported conglomerate and sandstone units of the upper member to represent non-turbulent, concentrated debris or density flow deposits that most likely accumulated in a subaqueous environment. Stratigraphic features in some lower member units include disorganized sand, organized sand–mud couplets, and graded bedding, which are generally consistent with concentrated density flow or turbidity current deposition.

The abundance of coarse-grained (up to boulder-sized) rock fragments in the upper member, including those derived from Yukon-Tanana basement, suggests that Faro Peak formation deposition was coincident with regional exhumation and tectonic erosion. For example, Knight *et al.* (2013) concluded that Early Jurassic extension along the Willow Lake fault of central Yukon resulted in the exhumation of Yukon-Tanana basement rocks from mid-crustal depths during the time of Faro Peak formation deposition. The recent plate tectonic model for the Whitehorse trough by Colpron *et al.* (2015) is broadly compatible with a strike-slip/transtensional setting for the Faro Peak basin along the Intermontane belt–ancient North American margin boundary. It follows that crustal-scale faults in the Faro region could have accommodated regional exhumation of Yukon-Tanana basement and adjacent Slide Mountain terrane. Although the Faro Peak formation was deposited along a convergent margin, we are investigating transtensional origins for the Faro Peak basin, including modern analogues in southern California (e.g., Ridge basin; Link, 2003) and Jamaica (e.g., Wagwater basin; Wescott and Etheridge, 1983).

Faro Peak formation rock units were sampled for petrographic and detrital zircon U-Pb-Hf studies at more than 20 locations during summer 2018. Petrographic data will constrain the framework composition of lower and upper member strata and document lateral or vertical changes in provenance. The youngest population of detrital zircon U-Pb ages will be used to constrain the maximum depositional age of lower and upper member rock units (e.g., Dickinson and Gehrels, 2009), whereas combined U-Pb-Hf data will identify specific provenance areas and regional crustal evolution of the Intermontane terranes. These results will be integrated with existing (Colpron *et al.*, 2015) and forthcoming (e.g., van Drecht and Beranek, 2017) detrital zircon U-Pb(± Hf) data from Lower to Middle Jurassic strata of the Whitehorse trough and Lower Jurassic foreland basin strata in the southern Canadian Rockies (Pană *et al.*, 2018) to better constrain Cordilleran tectonic evolution.

Field studies in summer 2019 will focus on the northwestern and southeastern extents of the Faro Peak formation in the southern Tay River map area.

Near Rose Mountain, we will investigate the contact relationships and stratigraphic architecture of lower member units that include basalt, chert, and mafic greywacke adjacent to the Vangorda fault (Fig. 3). The goal of this research is to ascertain if the lower Faro Peak formation in this location: (1) represents a Permian overlap assemblage between Yukon-Tanana and Slide Mountain terranes; (2) represents a fault sliver of Slide Mountain terrane (Campbell Range formation); or (3) represents a Late Triassic–Early Jurassic succession of basalt and related sedimentary rocks assigned to Yukon-Tanana terrane. Three isolated occurrences of Faro Peak formation occur in proximity to the Deno Cho Trail ~25, 30, and 45 km to the southeast of Faro (Fig. 2b), respectively, and include chert, mafic greywacke, and other rock units that may be similar to lower member strata near Rose Mountain. Field studies of these Faro Peak formation strata will therefore provide information about the timing and nature of stratigraphic units along the length of the Vangorda fault and their significance to understanding the Yukon-Tanana–Slide Mountain terrane boundary.

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