

This legend adopts a consistent, easily parsed, machine-readable format. Descriptive segments are separated by the pipe symbol, '|', as follows: composition | colour, texture | mineralogy | structure | other distinguishing features | interpreted environment, correlation, age (isotopic, fossil). All Nicola Goup 'formation' names used herein remain informal.

Layered Rocks

Anthropocene

basaltic trachyandesite | black, red-brown oxidzed surface, glassy, highly vesicular | microlites of clinopyroxene and plagioclase; xenocrysts of quartz, feldspar, and clinopyroxene | scoria, spatter, rare flows | commonly with embedded charcoal | dating of charcoal consistently shows contamination with post-nuclear testing carbon-14 (see Canil et al., 2018)

Quaternary

Valley basalt | black, dull grey weathered; highly vesicular | olivine-bearing| multiple, thin flows, columnar jointed || preserved as a sinuous semi-continuous escarpment adjacent to current drainages, which approximate paleovalleys that once channeled these lavas; locally rest upon interglacial sediments, therefore they are Pleistocene

Neogene

basalt flows, interflow breccia and oxidized reddish scoria | black fresh, dark brown to tan weathered; aphanitic, amygdaloidal to vesicular | plagioclase microlites, olivine phenocrysts; zeolite and chalcedony amygdules | local columnar jointing | volatilerich as indicated by interconnected vesicles | can be confused for similar, but younger flows of unit QVvb

EKv undivided; andesite, dacite, rhyolite flows, breccia and tuffs; minor sandstone and conglomerate

Penticton Group

dacite to rhyolite tuffs predominate, rare ash-flow tuff | greyish white, tan; aphanitic to fine-medium sparsely porphyritic, locally flow laminated, rarely welded | phenocrysts of grey quartz (common), orthoclase (rarely to 1 cm), biotite (common, rarely to 1.5 cm) ± acicular hornblende

Princeton Group

undivided; sandstone, conglomerate ||||| rare outlier of possible Allenby Formation overlying Tulameen ultramafite, and encountered by drilling at Copper Mountain mine

dacite to rhyolite flows, minor related breccia and tuffs | light grey groundmass | plagioclase, vitreous hornblende prisms (20%), ± oxyhornblende, biotite (1-2%), trace quartz, ±sanadine | flow laminated | widespread and centred on Fig Lake graben, thickest to the northwest on Spius Formation (Lower Cretaceous) as multiple cliff-forming flows, and thinning to the southeast and east of Shovelnose Mountain, locally as scattered outliers on Shea conglomerate (Jurassic)

andesite flows | light to dark grey; vesicular | plagioclase ± olivine phyric ||| high stratigraphically, atop sedimentary units of the

Allenby Formation; previously assigned to Upper Volcanic Formation (Read, 1987)

tuffaceous sandstone, minor siltstone, sparse layers of carbonaceous shale and coal; local rhyolitic vitric crystal tuff (Asp Creek and Tailings ash beds) | white to ochre-weathering | tuff contains biotite, quartz, plagioclase and sanadine crystal pyroclasts || waterlain vitric tuffs of both the Asp Creek and Tailing ashes are replaced by heulandite and clinoptilite; minor bentonite

carbonaceous shale, coal, minor sandstone, rhyolitic vitric-crystal tuff (Snowpatch ash) | grey, maroon || waterlain vitric tuff interval replaced by zeolites, heulandite and clinoptilite; minor bentonite. A similar rhyolite tuff, Princeton ash, higher stratigraphically in the Vermillion shale, lacks zeolite replacement

volcanic and quartz-pebble conglomerate, volcanic sharpstone conglomerate, coarse wacke | tan to brown |||| possible detrital sources include the Nicola Group and Nelson suite intrusions

arkosic sandstone, minor siltstone, rare shale; local basal boulder conglomerate | generally white, green-brown at the base |||| correlative with Coldwater Formation in the Merritt basin

Cedar Formation

intermediate compositions prevail, varying to felsic compositions in a heterogenous combination of flows and volcaniclastic rocks, and lesser sedimentary rocks | aphanitic to porphyritic textures | mainly plagioclase with or without pyroxene, hornblende, biotite and quartz

EPRCvsr lahar, pyroclastic breccia (?), minor flows; minor sedimentary interbeds | red or brown

Lower Cretaceous Spences Bridge Group Pimainus Formation

IKSPv undivided; and esitic to felsic flows, tuffs; minor sandstone, conglomerate ||||| probably equivalent to the Pimainus Formation

dacite flows| brownish orange to pinkish; porphyritic with glomerocrysts, rarely amygdaloidal | plagioclase to 4mm (15-20%), rare hornblende | massive with rare flow laminae | cliff-forming unit locally columnar jointed

dacitic vitrophyric flows, rare lapilli tuff or welded tuff | greyish weathering; black glass groundmass | medium-grained plagioclase phenocrysts (to 40%) | faint flow laminations locally, generally massive, devoid of layering | sparse entrained angular felsic lapilli | interpreted as a flow dome

- rhyolite flows; local volumetrically minor welded ash-flow tuff| green, weathers whitish mauve or reddish brown with alternating off-white and oxidized red to purplish flow laminations; lithophysae, devitrification to spherulites and nodules medium-size phenocrysts of plagioclase (10-20%) local columnar jointing (e.g. at the base and summit of Shovelnose Mountain)
- basaltic andesite and andesite flows; rare pyroxene-rich sandstone and conglomerate | grey-green and greyish maroon where oxidized; porphyritic, less commonly aphanitic or amygdaloidal | medium-grained plagioclase (20-30%) and chlorite-altered pyroxene (1-3%) ||| similar and esitic flow units occur at multiple stratigraphic levels, and require other distinctive bounding
- Spences Bridge stratigraphic units in order to distinguish these from identical flows characteristic of the Iron Mountain formation sandstone, pebble-cobble conglomerate locally predominant | subangular and rounded || sandstones medium thick, planar bedded

and locally cross-laminated; massive unstructured polymictic orthoconglomerate | common carbonaceous plant debris | distinctive mineralogy and felsic clasts supports local provenance from underlying ash-flow tuff (IKSPvif.pi), and abundant rounded granitic clasts represent mixing of detritus from an external source

heterolithic volcanic conglomerate; sandstone and siltstone | fine clastic rocks greenish-grey weathering to drab olive green; spheroidal weathering | minute angular plagioclase, traces of hornblende (?) and quartz grains | subhorizontal medium to thickly bedded, interlaminated siltstones with load casts, abundant carbonaceous debris and rare tree trunks | conglomerate (intervals to 30m thick) consists of unsorted subrounded to angular cobbles and boulders (1.5m max) composed of andesite to rhyolite compositions, derived from the Spences Bridge Group | coarse deposits are interpreted as debris flow cutting into,

and overlying, shallow water clastic rocks, that together form a lenticular deposit within unit IKSPvif.pi dacite to rhyolite ash-flow tuff; derived epiclastic interbeds (see unit IKSPvs) | light green matrix; locally weathers to porcelaneous flaggy fragments, and in some cliff exposures, large diameter cavities develop as a consequence of differential weathering

- predominantly lapilli, sparse blocks; angular to subangular | distinctive cognate pyroclasts of rhyolite are light green, off white and pink, aphanitic and lesser flow laminated, accidental granite, and abundant aphanitic and porphyritic andesite; distinctive crystal pyroclasts in trace quantities include quartz and biotite, and ubiquitous plagioclase | except for relatively thin welded intervals identified by fiamme, the unit is typically non-welded and very thick to massively bedded | rare carbonized tree trunks; carbonaceous plant debris is common in clastic beds near the base and top of the unit | represents an explosive, topographically controlled valley-fill deposit, and precursor to effusive rhyolite (unit IKSPvr)
- polymictic conglomerate, sandstone and siltstone interbeds | poorly sorted, matrix to clast-supported || well bedded sandstones, locally cross stratified | rhyolitic detritus (Spences Bridge provenance), also abundant granitic detritus and other lithologies indicate local derivation from underlying sources (i.e. Nicola Group) | heterolithic conglomeratic deposits, at or near base of

the Pimainus Formation, represent recurring tectonic instability as the Spences Bridge volcanism commences

Upper Jurassic to Lower Cretaceous

Bates chert conglomerate unit

chert pebble conglomerate with lesser sandstone, argillite and polymictic conglomerate layers near base | orange weathered; unsorted well rounded pebble to boulder-size clasts | grey, greenish and black chert clasts predominate | massive thick beds with sandstone lenses locally displaying low-angle cross stratification || youngest detrital zircon populations ~163 Ma and possibly as young as 134 Ma (Mihalynuk et al., 2016); on the basis of reported Lower Pleinsbachian (Lower Jurassic) radiolaria from chert clasts, a Cache Creek terrane provenance is suspected

Middle to Upper Jurassic

rhyolite flows and autobreccia, minor welded tuff | light green |||| comagmatic with the granodiorite marginal phase of the Osprey batholith; U-Pb TIMS age 163.2 ± 0.15 Ma (Mihalynuk et al., 2016)

andesite breccia, lesser flows and tuffs | dark green-brown | phenocrysts of plagioclase, ± pyroxene

conglomerate with abundant tuffaceous layers |||| stratigraphic lowest of three units in an outlier assigned to the Skwel Peken Formation; presumed to represent an extrusive equivalent of the Osprey batholith, marginal phase (unit MLJNgd)

Lower Jurassic

Tillery volcanic unit; andesitic flows, breccia, sparse interflow conglomerate | grey-green; fine to medium porphyritic, amygdaloidal | mainly plagioclase, minor pyroxene phenocrysts || radiating white zeolite amygdules | subaerial volcanic unit of uncertain age

Tillery volcanosedimentary unit; lapilli tuff, ash tuff mixed with pebble conglomerate and sandstone, siltstone | maroon | clasts are generally aphanitic to fine feldspar porphyries | poorly to well-bedded | recessive, rubbly-weathering interval | interpreted as the basal bed of the Tillery andesite that locally marks a disconformable contact with the underlying Voght basalt (unit uTrNEvb.tm)

Shea conglomerate unit || polymictic cobbles include granitic, aphanitic to porphyritic volcanic, siliceous mudstone, 'cherty' clasts in shades of grey, black and green | reddish oxidized, unsorted clasts in coarse sandstone matrix; red soil where poorly exposed | an otherwise strikingly similar unit, Harmon conglomerate (unit uTrNEHscp), contains abundant rhyolite and limestone cobbles; maximum depositional age from detrital zircons, <190, 185? Ma (dating site immediately west of map area)

Middle to Upper Triassic (and base of Lower Jurassic)

undivided; mafic to intermediate volcanic rocks with variable proportions of flows and pyroclastic rocks; rare limestone | shades of dark green to oxidized maroon | typically medium- to coarse-phenocrysts dominated by plagioclase, lesser clinopyroxene, ± scant hornblende

Shrimpton formation (Rhaetian to Hettangian)

siltstone and sandstone, minor argillite locally with rare off-white rhyolitic ash laminations; local impure limestone lenses or thin beds; scarce polymictic pebble conglomerate | grey-black to brown, commonly rusty || thin to medium-thickly bedded | calcareous argillite and limestone locally contain rare ammonoids and pelecypods and ichthioliths, no conodonts | marine sedimentary rocks onlapping the arc-derived clastic apron units represented by the Elkhart fomation and most of the lower Shrimpton formation; zircons extracted from rhyolitic ash tuff return an age of 200.2 ± 1.1 Ma

limestone || minor isolated thin beds or lenses ||| all samples collected for conodonts are barren suggesting the strata may be of earliest Jurassic age

trachybasalt flows and minor autoclastic breccia | grey-green | flesh-coloured, medium-grained analcime diagnostic, augite and plagioclase phenocrysts | isolated thin flows 0.3 m to \sim 10 m thick, mainly restricted to the Shrimpton unit, uTrNSHss.pt

- sandstone (tuffite) containing distinctive volcanic-fallout crystal-pyroclasts, polymictic conglomerate || trace quantities of minute (<2mm) crystal pyroclasts include copper-coloured biotite, apatite and quartz | well-bedded fine clastic interval typical, but locally as relatively thin beds within conglomeratic deposits | may contain carbonaceous plant debris, rare fossil crinoids |
- terrestrial arc-margin depositional setting monzonite cobble-rich conglomerate, sandstone | orange-weathering; subangular-subrounded monzonite and pyroxene-basalt clasts predominate | massive with thin bedded sandstone layers | may contain diagnostic volcanic-fallout crystal proclasts of
- biotite and apatite in the matrix; rare plant debris | suspected provenance from pluton unit LTrChd and Nicola volcanic rocks; proximal facies around Iron Mask batholith includes angular, coarse, ±copper-stained blocks
- Fairweather polymictic conglomerate unit; minor sandstone | red to green | clasts mainly of Nicola Group pyroxene-phyric basalt and andesite, lesser monzonite and diorite clasts from the Copper Mountain suite; subangular to subrounded, poorly sorted typically massive stuctureless beds with thin, faintly bedded sandstone intervals || immature arc-derived conglomeratic
 - deposits, previously interpreted as lahars (Preto, 1979), forming a terrestrial to littoral clastic apron that draped and prograded outward from the Nicola arc margin

Whistle Formation (late Norian to Rhaetian)

Copperfield breccia, and /or conglomerate | grey, buff and pink; well rounded and angular clasts to boulder size | limestone comprises >95% of clasts; matrix contains abundant plagioclase, guartz, chert and volcanic detritus | fine clastic layers display evidence of soft sediment deformation, chaotic bedding | depositional age inferred from cross-cutting Hedley intrusions, including Banbury and Larcan stocks and dated Toronto stock (~195.5 ± 1.2 Ma, Mortensen, 2014) widespread marker unit at the base of the Whistle Formation; formed by collapse of a Triassic platformal carbonate and west-directed gravity slide onto unconsolidated clastic facies of the Aberdeen Formation (Ray and Dawson, 1994)

Elkhart formation (previously called Paradise and Harmon successions, Mihalynuk et al., 2016)

- polymictic conglomerate, sandstone, locally prominent augite, \pm hornblende andesite porphyry flows | orange weathering;
- unsorted, rounded and subangular clasts || except for minor bedded sandstone, typically massive | mainly volcanic clasts (Nicola Group source), but locally medium-grained monzonite and diorite are predomint; rare gabbro and pyroxenite; and sparse carbonate | conglomeratic deposits record arc erosion and deposition as an outer arc clastic apron; timing of deposition
- inferred from 40/39Ar dates obtained from an intercalated hornblende-rich andesite flow (~210 Ma) and similar dike (~207 Ma) feldspathic sandstone, siltstone, rare argillite | brown to tan, rusty weathering; fine to medium grained | indistinct planar beds up
- to metres-thick || generally as thin discontinuous beds within unit uTrNEscp; may be easily confused with similar thick isolated deposits of unit uTrNIsw
- basalt and andesite flows, volcanic breccia; minor conglomerate | dark green, medium to coarse porphyritic and amygdaloidal textures | plagioclase, pyroxene, ±acicular hornblende ||| 40/39Argon dates on hornblende andesite flow (~210 Ma) and similar dike cross cutting unit uTrNEscp (~207 Ma); in absence of distinctive hornblende-phyric flows, this unit is difficult to distinguish from mafic flow unit, uTrNIvmi, of the Iron Mountain formation
- limestone | grey, locally hematitic ||| thin lenticular beds



basalt flows | dark green | fine to medium-grained | augite-feldspar-phyric | pillowed | commonly strong epidote-chlorite alteration | probably interfingers with and underlies rhyolite of unit mTrNMvr

Middle to Upper Triassic

Mapping contributions:

Gerri McEwan (2014); Yao Cui (2017-18)

Mitchell G. Mihalynuk (2012-18); Larry J. Diakow (2013-18); James M. Logan (2012-13);

Martha A. Henderson (2013-14); Johannes Jakob (2013); Theron Findley (2014-15);

Permian, Triassic, Jurassic, Cretaceous, Paleogene..... (f) (f) (f) (f)

Road (divided highway, paved road, gravel road)

..... 🔺

Field station ...

Mihalynuk, M.G., and Diakow, L.J., 2020. Southern Nicola arc geology. British Columbia Ministry of Energy, Mines and Low Carbon Innovation, British Columbia Geological Survey Geoscience Map 2020-01, 2 sheets, 1:50,000 scale map plus supplement. This is part of a broader compilation:

Diakow, L.J., and Mihalynuk, M.G., in press. Digital geology compilation of southern Quesnel terrane. In: Digital geology of British Columbia. British Columbia Ministry of Energy, Mines and Low Carbon Innovation, British Columbia Geological Survey, https://www2.gov.bc.ca/gov/content/industry/mineral-exploration-mining/british-columbia-geological-survey/geology/bcdigitalgeology

Aberdee uTTrSASss	en Ridge formation (Stemwinder facies; Stemwinder Formation of Ray and Dawson, 1994) siltstone, sandstone, rare thin limestone grey; fine- to coarse-grained turbiditic character locally provisional subdivision representing the uppermost and youngest Stemwinder facies strata containing late Norian-Rhaetian conodont fauna (Ray and Dawson, 1994) and/or corresponding maximum depositional isotopic ages inferred from detrital zircons; the lower contact is arbitrarily located, and thought to be a disconformity with underlying older Stemwinder strata, unit uTrSASsf, which contains conodonts ranging from late Carnian to middle Norian; the upper stratigraphic contact is locally marked by the distinctive
uTrSsf.pt	Copperfield breccia, unit uTrNWCscb argillite, siltstone, sandstone, minor polymictic conglomerate, thin limestone beds or lenses; sparse interbeds of crystal and lapilli tuffs, tuff breccia, and basaltic to andesitic flows black, grey to grey-green calcareous to siliceous matrix in fine clastic rocks laminated to very thinly bedded, locally graded gradational contacts between fine clastic and, volcanic rocks including local pillowed andesite, lithic tuff and pyroxene-bearing rocks typical of the Nicola Group marine clastic unit containing late Carnian conodonts tentatively re-assigned to the Slocan Group; deposited close to the Nicola arc, contemporaneous with exclusively sedimentary facies of the Aberdeen Ridge formation near Hedley
Intrusive Rocks	
Quater	nary
QVhd	gabbro interpreted as a volcanic neck and possible feeder to unit QVvb flows
Eocene	
Coryell si EChg	uite rhyolite yellow, buff to white, aphyritc to megacrystic porphyritic K-feldspar, smokey quartz dike, possible volcanic neck east of Missezula Lk includes possible feeder to Penticton Group strata
Early C	retaceous
EKdmz	monzonite, syenite shades of reddish orange; medium to coarse grained, equigranular or porphyritic <5% chlorite-altered mafic minerals isolated small stocks which may be cogenetic with nearby monzonite-syenite dikes that comprise a northerly-trending swarm that crosscut Spences Bridge Group strata
EKg	leucogranite to mafic microdiorite pink to dark grey formerly included with 'Allison Creek stocks' of Preto (1979), nomenclature now abandoned
EKgd	granodiorite, quartz monzonite, minor granite grey to pink; medium to coarse grained biotite-hornblende mafic xenoliths common includes several undated, poorly exposed intrusives near the summit of Shovelnose Mtn. and Summers Ck. stock
EKhg	granitic, felsite, syenitic to monzonitic dikes white, buff, orange, pink; typically coarse-grained porphyries and aphanitic textures plagioclase, ±orthoclase, ±quartz, biotite, ±hornblende rarely flow banded typically as multiple, parallel north-trending dikes in swarms (evident at Copper Mountain deposit, where known as 'Mine dikes'); contact relationships elsewhere suggest that felsic dikes were emplaced synchronously adjacent to dioritic dikes (unit EKhd) comagmatic with the Verde Creek pluton, and probable feeder dikes to volcanic units of the Spences Bridge Group
Late Ju	irassic
LJd	diorite grey, rusty weathered; fine grained hornblende-bearing dike containing blebs, veinlets and disseminations of chalcopyrite in the Southwest zone at Miner Mountain prospect
Middle to Late Jurassic Nelson suite (Osprey batholith)	
MLJNgg.tm	arapite, arapedierite L white to pickich arey L modium to coarce arained L with or without measurets of potacsium foldenary up to
MLJNgd	granodiorite, quartz monzodiorite; minor diorite and quartz diorite greyish pink, medium to coarse equigranular up to 15 % mafics dominated by biotite and lesser hornblende border phase of the Osprey batholith
Early Jurassic	
	e suite (Pennask and Bromley batholiths) granodiorite predominates, local tonalite to quartz diorite biotite-hornblende bearing plug/stock sized bodies peripheral to larger
EJWgd	Wild Horse, Pennask and Bromley batholiths which are predominantly composed of this unit
EJWgt	tonalite to quartz diorite with late, pink pegmatite and aplite dikes at the margin (Pennask); granodiorite with diorite and quartz diorite localized near border (Bromley) light grey to pink; medium to coarse grained, equigranular hornblende and biotite generally <15%; sphene-rich at Pennask amphibole ± biotite hornfels developed locally at contact with country rocks (unit uTrNmh)
EJWd	diorite, quartz diorite, monzodiorite, rare gabbro grey; medium to coarse grained, holocrystalline and porphyritic ubiquitous pristine hornblende (<20%) small stocks and dikes
EJWdg	gabbro, quartz gabbro, diorite dark green; medium to coarse grained, equigranular; locally gabbroic pegmatite hornblende ± biotite, or pyroxene minor isolated intrusive phases peripheral to Pennask and Bromley batholiths; includes Mount Riordon stock, probably a satellite of the Bromley (Ray and Dawson, 1994); U-Pb age of ~193 Ma (Mihalynuk et al., 2016)
Late Triassic	
LTrNShf	rhyolite light green, aphanitic to sparsely porphyritic plagioclase phenocrysts local sub-horizontal columnar joints chalcedony and comb-textured veinlets interpreted as hypayssal intrusions comagmatic with the Castillion member, Selish formation
Copper N	Iountain suite
LTrChyx	monzonite breccia breccia of hydrothermal origin carrying copper mineralization at Big Kidd and Ketchan properties
LTrChd	monzonite, syenite, feldspar porphyry orange, salmon pink and grey-green, medium-grained porphyries predominantly zoned plagioclase, potassium-feldspar, augite, ±hornblende locally brecciated interpreted as subvolcanic intrusives, locally associated with mineralized hydrothermal breccia (unit LTrChyx, Big Kidd and Ketchan properties); also probable erosional source for monzonite clast-rich conglomerate in the Shrimpton formation (unit uTrNSHsco); elsewhere presumed association with breccia and tuffs at Dufferin Hill (Iron Mask batholith)
LTrCd	diorite, syenodiorite, quartz diorite, gabbro, diorite breccia fine to medium grained; equigranular to porphyritic pyroxene, less commonly hornblende-bearing intense saussurtization and potassium feldspar alteration where they host mineralization (e.g. Miner Mtn, Ketchan and Axe developed prospects) main distribution of plug-size bodies in a north-trending tract between Princeton and Merritt, also includes isolated plugs, some in contact with gabbro-pyroxenite (unit LTrCdg) intruding the Nicola Group, exposed between Tulameen ultramafite and Copper Mountain stock
Mount Pike suite (Allison batholith)	
LTrPgg	granite, quartz monzonite pink to oxidized reddish orange; medium grained, equigranular, locally miarolitic chloritized biotite (1-5%) granite, the youngest phase (circa 223 Ma) of the Allison batholith, extends south and southwest beneath Spences Bridge Group strata, resurfacing with other phases of the batholith as satellite intrusions
LTrPgd	granodiorite pink or greyish, medium grained the granodiorite phase of the Allison batholith extends to the south and southwest beneath Spences Bridge Group strate, resurfacing with other phases of the batholith as satellite intrusions.

LTrPad granodiorite | pink or greyish, medium grained |||| the granodiorite phase of the Allison batholith extends to the south and southwest beneath Spences Bridge Group strata, resurfacing with other phases of the batholith as satellite intrusions

diorite, minor quartz diorite, rare gabbro | dark green, medium to coarse grained, inequigranular | pyroxene and/or hornblendebearing, chlorite-epidote altered ||| diorite is presumed to be the oldest phase of the Allison batholith, which extends to the south and southwest beneath Spences Bridge Group strata resurfacing near Tulameen townsite as a multiphase satellite intrusion, and farther northwest, the batholith's extent is considered represented by small isolated dioritic apophyses





Energy, Mines and Low Carbon Innovation

BC Geological Survey

BCGS Geoscience Map 2020-01 Sheet 2 of 2

NTS 92H/7NE, 8NW, 9W, 10E, 15E, 16W, 92I/1SW, 2SE

Southern Nicola Arc Geology

Mitchell G. Mihalynuk and Larry J. Diakow

SUPPLEMENT

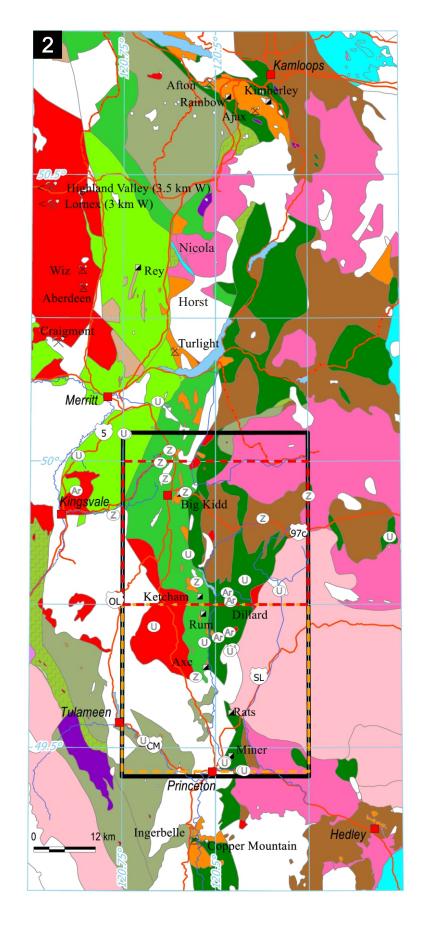
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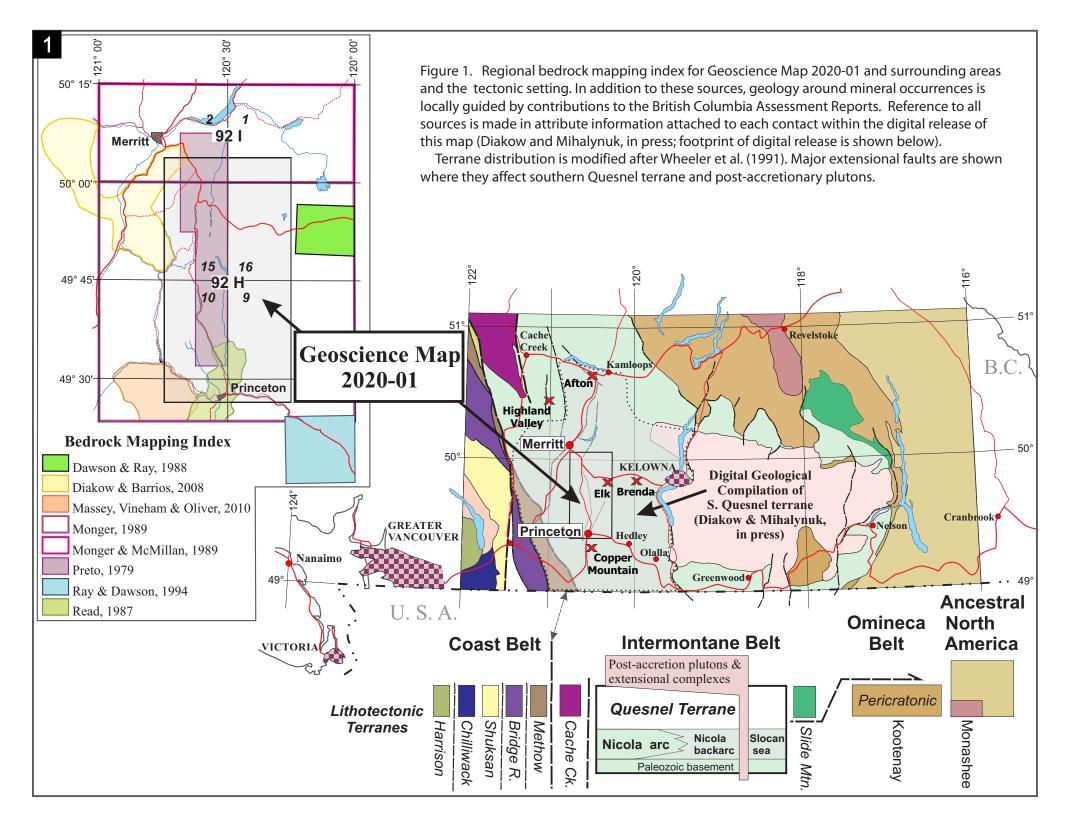
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Overview

Geoscience Map 2020-01 represents an area of approximately 2000 km² in southwestern British Columbia, extending from southeast of Merritt to Princeton (Fig. 1). It is centred on volcanosedimentary rocks of the Late Triassic Nicola arc, which is endowed with significant porphyry copper-gold-molybdenum-silver deposits. Active mines are in the south, near Princeton (Copper Mountain), and in the north, near Kamloops (Highland Valley and New Afton; Figs. 2, 3). About a third of the map area is underlain by Jurassic intrusions that cut deformed Nicola arc strata, mainly in the east. Volcano-sedimentary strata of both the Spences Bridge Group (Early Cretaceous) and Princeton Group (Eocene) unconformably overlie the early Mesozoic rocks, particularly in the western part of the map area. All Eocene and older rocks are faulted, tilted, and locally folded beneath scattered remnants of Miocene to Pleistocene Chilcotin Group and 'Valley basalts'. Rare occurrences of unnamed supraglacial volcanic spatter are limited to two areas, each less than 100 metres in diameter, and are important examples of possibly the youngest subaerial volcanic rocks in British Columbia (Canil, et al., 2018).







History of work

The earliest geological mapping in the area was by Dawson (1879) who named the Nicola Group. Systematic regional mapping was conducted in the north by (Cockfield, 1948) at ~1:250 000-scale. Within and adjacent to the map area, detailed mapping focussing on the Nicola Group began with Schau (1968; Fig. 1) and was expanded to the central corridor of the southern Nicola arc with local mapping (Christopher, 1973; Lefebure, 1976). These studies were integrated with 1:50 000 scale mapping between Merritt and Princeton (Preto, 1979), and all were incorporated into regional 1:250 000-scale maps produced by Monger (1989) and Monger and McMillan (1989). In the west and northwest, mapping by Diakow and Barrios (2008) focussed on Early Cretaceous volcanic rocks. In the south, early regional mapping was by Rice (1947) at ~1:250 000-scale, followed by more detailed mapping of coal-bearing Eocene rocks in Princeton basin by McMechan (1983) and Read (1987), which was incorporated into 1:50 000 scale mapping by Massey et al., (2010).

Owing in part to its important metal endowment, the southern Nicola arc has been extensively explored (see reviews in Preto, 1979; Mihalynuk and Logan, 2013a, 2013b; Mihalynuk et al., 2014a, 2015; and references therein). Since 2012, the Southern Nicola Arc Project (SNAP; Mihalynuk and Logan, 2013a, 2013b; Mihalynuk et al., 2014a, 2014b, 2015, 2016) has remapped at 1:20 000-scale an area situated between the producing deposits at Copper Mountain to the south (Preto and Nixon, 2004) and Iron Mask batholith to the north (Logan and Mihalynuk, 2006; Fig. 2). Geoscience map 2020-01, is a synthesis of results from the Southern Nicola Arc Project (SNAP) at 1:50 000-scale. It benefits from new geochronological data (Fig. 4) and it presents a redefined Nicola Group with new informal lithostratigraphy (Fig. 5).

Regional geological setting and tectonic history Southern Nicola arc has traditionally been considered rooted on Paleozoic basement elements (Read and Okulitch, 1977)

included as part of the Quesnel terrane (Coney et al., 1980). These comprise disparate stratigraphy with sedimentary rocks that contain fossils as old as Ordovician (Read and Okulitch, 1977; Pohler, et al., 1989) to Permian, and volcanic rocks of both island and MORB tectonic affinities (Massey and Dostal, 2013; Mortensen et al., 2017). At the latitude of the present study area, but beyond its borders, diverse oceanic rocks comprise Quesnel basement. West of Princeton, these rocks have been mapped as the Eastgate-Whipsaw assembblage (Fig. 6; Massey et al., 2010) and dated as Early Permian (~281 – 283 Ma; Oliver, 2011). East of Hedley, the Quesnel basement rocks have been referred to by many names. Those closest to the southern part of the map area are the Apex Mountain complex (Monger, 1989); farther east are the Kobau, Knob Hill, Attwood, and Anarchist 'groups' or 'assemblages'. Those near the northern part of the map area are the Harper Ranch and Chapperon groups. Protolith ages range from Devonian to Early Permian and magmatic components are chemically and isotopically primitive, with little evidence of a continental margin substrate (Ghosh, 1995; Massey et al., 2013; Massey and Dostal, 2013). However, evidence of an old continental margin affiliation is seen in Precambrian detrital zircon populations recovered from Paleozoic basement stratigraphy in the Apex Mountain complex (Mortensen et al., 2017). Similar detrital zircon populations are also found in overlying Upper Triassic Slocan Group in strata of the former Hedley basin that lie unconformably on Apex Mountaion complex unpublished data). Erosion and transport of these old zircon grains directly from western North America may have occurred during the Triassic, but they could also be recycled from Paleozoic sedimentary strata of the Apex Mountain complex that had received North American-sourced detritus.

Paleozoic arc rocks are known regionally as the Harper Ranch Group and are widely considered as originating on the flank of western North America as the arc sparked to life in the Devonian (Monger et al., 1972; Monger, 1977; Mihalynuk et al., 1994; Ferri, 1997), as early as ~390 Ma (Massey et al., 2013). Most paleogeographic models invoke extensive back-arc basin formation as this Paleozoic Quesnel arc was rifted from its continental margin homeland (e.g., Harms, 1986; Ferri, 1997). It may have rooted in the continental margin to the south forming a hybrid oceanic arc/back-arc basin like the modern Aleutian arc (Fig. 7; Nelson, 1993; Mihalynuk et al., 1994). As the back-arc basin grew to oceanic proportions, Quesnellia apparently became sufficiently isolated from North America to permit the colonization of endemic organisms, the fossil remains of which are not seen in adjacent parts of cratonic North America today (Ross and Ross, 1983, 1985; Belasky et al., 2002; see discussion in Roback and Walker, 1995, and Ferri, 1997).

Consumption of the overgrown back arc basin is thought to have began in the Permian. However, evidence for a subduction complex between Quesnel terrane and North America is lacking in central BC (e.g. Ferri, 1997) and in southern BC, even evidence of arc magmatism is scarce, limited to clasts in sedimentary rocks (Beatty et al., 2006); although it has been

Southern Nicola Arc Project field mappers Mitchell G. Mihalynuk (2012-18); Larry J. Diakow (2013-18); James M. Logan (2012-13); Martha A. Henderson (2013-14); Johannes Jakob (2013);

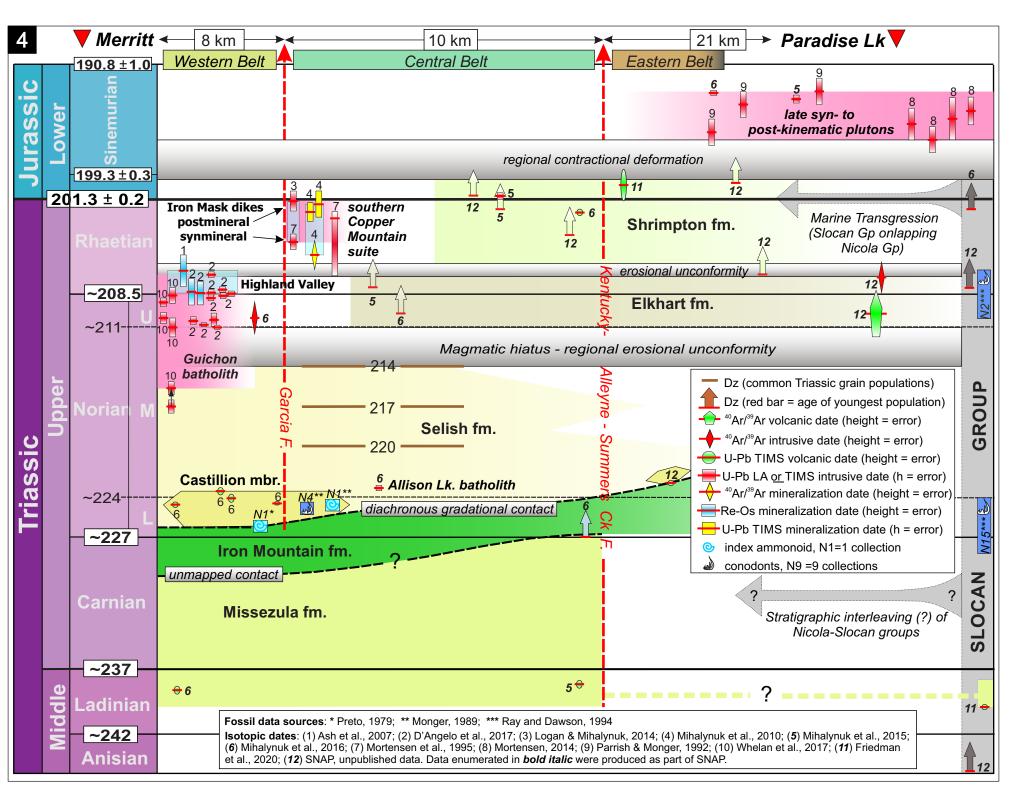
Theron Findley (2014-15); Gerri McEwan (2014); Yao Cui (2017-18) Age determinations

Isotopic dates by R. Friedman (UBC); Microfossil identifications by M. Orchard (MJO Microfossil Services)

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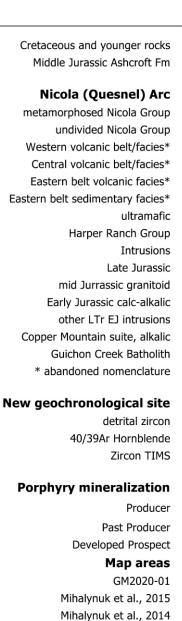


epochs are shown by transparent blue boxes; GC = Guichon Creek suite, CM = Copper Mountain suite.

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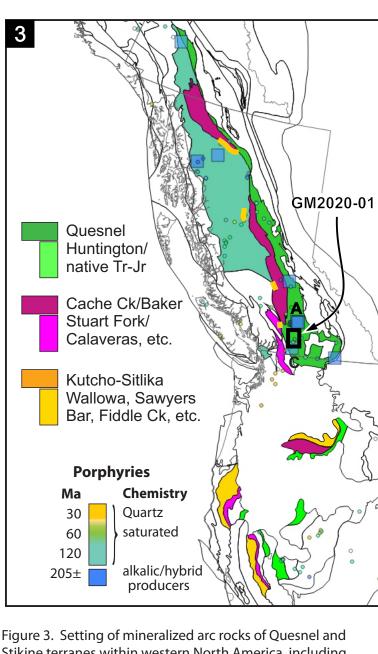
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Stikine terranes within western North America, including probable correlative arc rocks in the western USA . A prolific Late Triassic Cu-Au±Ag mineralizing event, mostly ~205 ±5 Ma (Logan and Mihalynuk, 2014), coincides with a major pulse of alkalic porphyry magmatism during late Stikine and Quesnel arc construction. A and C denote Afton and Copper Mountain alkalic porphyry deposits. Calc-alkalic deposits within the Guichon batholith just northwest of the GM2020-01 map area, are also part of this mineralizing epoch. Despite similarities in the tectonic fabric of the western USA, the alkalic porphyry belt is unknown there.

suggested that Apex Mountain complex and the Eastgate-Whipsaw belt are a Paleozoic subduction complex (Mortensen, et al., 2017) and arc (Oliver, 2011; Fig. 6). Whether subducted or telescoped, collapse of this basin left a trail of ophiolitic relicts known by various terrane names, most commonly "Slide Mountain" in BC and "Angayucham" farther northwest, in Alaska. In between, in Yukon, it includes a ~400 km-long tract of blueschist and eclogite occurrences adjacent an intra-oceanic arc (Parsons et al., 2019; juvenile Yukon-Tanana terrane of van Staal et al., 2018), probably correlative with Quesnel terrane. In Middle to Late Triassic time, subduction of ocean lithosphere flipped to beneath the outboard side of Quesnellia to form the Cache Creek terrane accretionary complex that contains Late Triassic blueschist best represented in central BC (Ghent et al., 1996; Struik et al., 2001). Above the subducting Cache Creek ocean lithosphere grew the Nicola arc (Fig. 7), the central feature of GM2020-01. In the back-arc, marine sedimentary rocks of the Slocan Group were deposited on a disconformable contact above Permian strata (Fig. 6), and may tie the arc to the ancient continent margin (Klepacki, 1983), but demonstrating such ties is confounded by interveaning zones of faulting and intense folding. Conodonts recovered from isoclinally folded Slocan Group at Hedley (previously Nicola Group; Ray and Dawson, 1994) range from Late Carnian to Rhaetian (Orchard, 2017; Fig. 5), and a comparable age range of Carnian to Late Norian from strata on the continental margin (Orchard, 1985, 2006). Detrital zircons corroborate the Rhaetian age for uppermost Slocan strata at Hedley (SNAP, unpublished data) and west of Salmon River (Schiarizza, 2017, unpublished data 2016). Also, several older conodont collections of Early Anisian age for rocks previously assigned to the Harper Ranch Group (Thompson et al., 2006), and a Ladinian age from an unassigned thin limestone unconformable on deformed Paleozoic basement near Olalla (Read and Okulitch, 1977) are regarded as older stratigraphic remnants of the Slocan Group, with the latter equivalent to oldest dated volcanic strata in the Nicola Group.

By the Early Jurassic, Quesnel and Stikine terranes started to be swept up against North America, which was accelerating westward as Pangea fragmented and the new Atlantic Ocean grew. Quesnel terrane was repatriated with the North American continental margin by ~185 Ma (Nixon et al., 2020), but final buckling and entrapment of exotic oceanic rocks of the Cache Creek terrane between northern Quesnel and Stikine terranes was apparently not completed until the Middle Jurassic, ~174 Ma (Fig. 7; Monger and Ross, 1971; Ricketts et al., 1992; Mihalynuk et al., 2004) and was probably synchronous in the south (e.g., Cordey, 2020). Collapse of the remnant Cache Creek ocean basin in the map area is possibly recorded by chert pebble and cobble conglomerate of the Bates unit (IKBsco; Fig. 5) which contain Permian (Guadalupian) and Triassic (Norian) radiolaria (Cordey, unpublished). Final demise of Cache Creek subduction was followed by a vigorous pulse of magmatism along the Intermontane Belt attributed to slab break, which welded the Intermontane oceanic plate to the newly reconfigured western margin of North America (Mihalynuk et al., 2004). In the GM2020-01 area, this magmatism is represented by volcanic rocks of the Skwel Peken Formation, and by the Osprey Lake batholith of the Nelson suite. which hosts the Elk gold deposit near Siwash Lake.

Like most of the Intermontane Belt, there is little sign of volcanic deposition in the Late Jurassic and early Early Cretaceous when ocean lithosphere newly welded to the leading edge of North America probably subducted westward beneath the Insular Superterrane (Dickinson, 2004; Sigloch and Mihalynuk, 2013, 2017). However, with continued westward drift of North America, the interveaning ocean basin was consumed, leading to diachronous collision of microcontinental Insular Superterrane (Monger et al., 1982; Sigloch and Mihalynuk, 2017) that shuffled rocks along the ancestral continental margin, southward. Crustal thickening of the western Nicola arc (Oliver, 2011) and a lead loss event in detrital zircons (150 140 Ma) may record this collision.

In Late Cretaceous, collision with a massive oceanic plateau (Livaccari et al., 1981; Liu et al., 2010) on the northwest subducting Farallon plate coupled the continental margin, which translated rapidly northward (Sigloch and Mihalynuk, 2013) as revealed by paleomagnetic measurements of the ~104 Ma Spences Bridge Group and coeval volcanic rocks west (Irving et al., 1995; Enkin, 2006). The appearance of Spences Bridge Group rocks, which extend outside the western part of the map area (Thorkelson and Rouse,1989; Diakow and Barrios, 2008), marks the end of a diachronous magmatic hiatus along the

Figure 4. Time-space plot showing the distribution of recently published and new geochronological age constraints for the southern Nicola arc and constituent formations that we propose herein. Also included are age data from the Hedley area, herein mostly correlated with the Slocan Group. Belt designations are for cross reference with historical literature (also on Fig. 2); they have been abandoned because strata demonstrably span belt boundaries. Ages of porphyry mineralizing

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leading edge of North America. Spences Bridge Group magmatism is probably related to slab break following a shift of subduction at this latitude from the inboard to the outboard margin of the Insular Superterrane. Important epithermal gold mineralization is developed within the Spences Bridge Group rocks. Collision of one final arc terrane in Early Eocene (~55-50 Ma) led to the modern plate margin configuration and underplating of the Pacific Rim terrane seen on Lithoprobe deep seismic profiles (Hyndman, 1995). Subsequent to 50 Ma, all but southwestern-most British Columbia became a transform margin above a growing slab window. Unsupported by a subducting plate, and heated from below by newly subjacent hot asthenosphere, the Cordillera collapsed, leading to widespread extensional core complexes (Brown and Journeay, 1987; Parrish et al., 1988) and mainly explosive felsic magmatism that was generated by melting Quesnel terrane arc roots. This collapse-related magmatism is recorded in the map area by rocks of the Princeton and Penticton Groups. Associated clastic strata preserved in extensional basins host coal measures that were economically important during early European settlement of British Columbia. Extension and deposition of Princeton Group volcanic and sedimentary rocks and outpourings of alkaline magmatism recorded by the Chilcotin Group (Neogene) largely influenced the modern landscape, with further modification by Quaternary glaciation. Late and post-glacial Valley basalts locally modified drainages. Rare scoria deposits (Anthropocene) found in the map

Redefined Nicola Group

area are volumetrically insignificant, covering at most one hectare.

Magmatic and sedimentary units of the southern Nicola arc were previously partitioned into three subparallel belts separated by northerly trending faults (Preto, 1979; Monger, 1989; Figs. 2, 4): 1) a Western belt distinguished by felsic volcanic rocks and limestone; 2) a Central belt consisting mainly of mafic volcanic rocks, comagmatic plutons, and locally prominent laharic rocks; and 3) an Eastern belt composed mainly of sedimentary rocks. Fossils from the volcanic-dominant western and central belts previously restricted timing of Nicola Group deposition to Late Triassic. The mainly sedimentary Eastern belt lacked fossils, inhibiting internal arc correlation; yet despite separation by a regional fault from the other belts, it was considered a lateral facies of belts to the west (Preto, 1979).

Rocks of the Eastern belt are particularly well preserved in the Hedley basin where they comprised formations of the Nicola Group (Ray and Dawson, 1994), but are now believed to represent western exposures of the Slocan Group (Figs. 4-6). In southwestern Quesnellia, the Slocan Group is a marine sequence that is a time-equivalent deep-basin corollary of the adjacent Nicola Group island arc strata. It is suspected to have periodically dominated deposition, either interdigitating or onlapping Nicola arc stratigraphy during Late Triassic sea level fluctuations, particularly in Carnian and Rhaetian times. Building on earlier pioneering work on the Nicola Group, recent detailed mapping conducted during SNAP, and 25 new radioisotopic age determinations (Mihalvnuk et al., 2014a, 2015, 2016; Friedman et al., 2016) leads us to abandon historic usage of 'Belt' terminology, replacing it with a lithostratigraphy that is intended to redefine the Nicola Group within a segment of the Nicola magmatic arc in southwestern Quesnel terrane. Uranium-lead geochronology now confirms lithostratigraphic ties for many kilometres along the arc, and importantly, new lithostratigraphic units demonstrably span historic belt boundaries, with felsic pulses dated at \sim 239 Ma and \sim 224 Ma in what was previously the Western belt; \sim 238 Ma, 224 Ma and \sim 202 Ma in what was previously the Central belt; and, 223 Ma and ~200 Ma in what was previously the Eastern belt. Growth of the Nicola arc began in Middle Triassic (ca. 239 Ma) and continued through erosional unconformities (~214-211 Ma, and ~207 Ma), that preceded emplacement of calc-alkalic and alkalic porphyry copper deposits, and arc termination in earliest Jurassic (~200 Ma).

Nicola Group Lithostratigraphy

Layered rocks in the southern Nicola arc are subdivided into five informal formations, from oldest to youngest: Missezula, Iron Mountain, Selish, Elkhart, and Shrimpton (Figs. 4, 5). Nowhere have complete sections of any of these units been identified. Where possible, aggregate thickness of units is estimated from least disturbed sections in which bedding attitudes are consistent (Fig. 5, inset). Missezula formation (new name)

The Missezula formation (previously referred to as the Missezula Mountain rhyolite (Mihalynuk et al., 2015) and Western belt rhyolite (Mihalynuk et al., 2016) is the oldest stratigraphic unit of the southern Nicola arc, established by felsic rocks with equivalent U-Pb TIMS dates (~239 - 238 Ma) found in widely spaced areas near Coalmont in the southwest and, centrally, near Missezula Mountain. Felsic rocks east of the map boundary near Pennask Mountain give an equivalent ~240 Ma date (Friedman et al., 2020), are considered a correlative with the formation. Dated rhyolitic rocks at this site apparently are stratigraphically below conglomerate forming the basal unit, re-designated Stemwinder facies in Aberdeen Ridge formation of the Slocan Group. Together these localities define a nascent arc-volcanic tract more than 60 kilometers long that bridged Nicola arc-axis and marginal Slocan basin settings in Ladinian time. Internal stratigraphy of the formation is unknown, and the nature of stratigraphic contacts have not been clearly established.

A 400-metre-thick section near Coalmont is distinguished by rhyolite flows and tuffaceous deposits underlain by pillow basalts of unknown thickness and undetermined age. Epiclastic beds rich in quartz and felsic grit inferred to sit in the upper parts of the Missezula formation, give an \sim 227 Ma maximum age of deposition for contained detrital zircons (Fig. 4). Iron Mountain formation (new name) The Iron Mountain formation is the most widespread division of the Nicola Group in the SNAP area where thickness

estimates are speculative. However, from a continuous, unfaulted volcanic section at Iron Mountain where the top contact is defined and base buried in Coldwater River channel, it exceeds 1.5 km thickness. Undoubtedly, thicker intervals exist in the east half of the map area, but discontinuous exposure and a possibility of faults thwart reliable estimates. Plagioclase and/or augitephyric fragmental and flow rocks of basalt and andesite composition predominate, with lesser bedded intervals composed of locally derived volcanic grit and scarce limestone. A general heterogeneity attributed to abrupt volcanic facies changes is typical of Iron Mountain volcanic constituents, and it hinders internal subdivision, boundary recognition, and correlation. Iron Mountain subunits were thermally metamorphosed by the Allison Lake batholith, a composite body with the youngest recognized granite phase dated at ~223 Ma (Fig. 4). Biohermal limestone associated with mafic volcanic and volcano-

sedimentary beds at several localities adjacent to the study area, and included as part of the Iron Mountain formation, contain conodonts of Late Carnian age. Selish formation (new name)

The Selish formation overlies the Iron Mountain formation across a diachronous gradational boundary that is well dated between 224 Ma and 223 Ma, based on locally intervening Castillion member at the base. The Castillion member is a composite of rhyolitic pyroclastic rocks interbedded with feldspathic wacke, limestone and less commonly, basalt flows in intervals up to 300m thick. Together these lithologies form a marker interval which is traceable between representative sections at Castillion Creek, Iron Mountain, Hamilton Creek and Kane Valley, scattered within a 20 km radius east and south of Merritt. Relative proportions of constituent lithologies varies as does aggregate thickness between sections. Foremost are rhyolitic fragmental rocks, showing welded texture and accretionary lapilli tuff horizons, features that provide the first direct evidence of subaerially erupted rocks. These felsic deposits repeatedly alternate with marine carbonates, recording incremental emergence in this sector of the Nicola arc. Precise conodont and ammonoid fossil ages show that the Castillion member spans the lower to middle Norian sub-stage boundary. Rhyolite interbeds containing zircons allow for an intercalibrated age of the substage boundary at 224 Ma.

An additional 600 m of Selish formation overlies the Castillion member, that includes widely spaced layers of welded gnimbrite and accretionary tuff, wacke, minor conglomerate with mafic flows. Repetition of subaerial felsic rocks, and a notable absence of carbonate in this section, reveals deposition in terrestrial conditions that prevailed throughout this thickest section at Selish Mountain. Exposures near Selish Mountain are considered to have high stratigraphic placement in the Selish formation, and nearby, the Coldwater pluton, which intrudes and thermally alters these strata, is dated at ~210 Ma, establishing the youngest age limit for the terrestrial deposits. Elkhart formation (new name)

The Elkhart formation comprises rocks previously included in the Paradise Lake and Harmon successions of Mihalynuk et al., 2015. This unit (former Paradise assignment) is well displayed between Elkhart and Boot lakes where it is composed mainly of polymictic conglomerate and admixed pyroxene-plagioclase-rich greywacke. Conglomerate clast types are mainly augite-basalt porphyry and hornblende-augite-basalt porphyry, monzonite, diorite, and relatively scarce limestone, gabbro and pyroxenite; all lithologies of the Nicola Group or nearby comagmatic plutons.

Mafic flows form discontinuous beds and locally thick accumulations within the clastic deposits. Several compositional class of basalt to basaltic andesite porphyries exist, distinguished by the relative proportions of plagioclase, hornblende and pyroxene phenocrysts. Isolated, thin dikes intrude the polymictic conglomerates. ⁴⁰Ar/³⁹Ar dates on hornblende from a hornblende-phyric flow and from a dike cutting sandstone are \sim 210 Ma and \sim 207 Ma, respectively. An outlier of Elkhart formation in Kane Valley (former Harmon succession) southeast of Merritt differs from facies to the east near Elkhart Lake. A conspicuous, maroon-weathering basal conglomerate (Harmon conglomerate, unit uTrNEHscp) of substantial thickness (~ 560 metres), underlies the valley bottom and exhibits an abrupt erosional unconformity with underlying

carbonate of the Castillion member, Selish formation. Clasts in the conglomerate are flow-banded rhyolite, dacite, and limestone boulders derived exclusively from the Selish formation. It grades upwards into recessive maroon sandstone interbeds in a volcanic-dominant 'Voght' subunit (uTrNEva, vb) in which lower andesite flows are overlain by an interval of distinctive coarse bladed plagioclase porphyritic basalt flows collectively forming up to 750 metres of section. The youngest detrital zircon populations from the Harmon conglomerate have returned maximum ages for deposition on detrital zircons of <222 (peak, with youngest multigrain population \sim 208), and \sim 220 Ma (peak, with youngest reliable multigrain population \sim 213) from a sandstone bed positioned higher stratigraphically, close to the contact with the overlying 'Voght' subunit. Shrimpton formation

The Shrimpton formation (previously referred to as Shrimpton succession in Mihalynuk et al., 2015) is the youngest stratigraphic unit of the Nicola Group. Widespread in the central and eastern parts of the map area, it comprises three main depositional subunits that unconformably overlie the Elkhart formation. Stratigraphic lowest and oldest is a monzonite clast-rich conglomerate up to 390 m thick that occupies an eastward-emplaced thrust panel, the trace of which is well exposed along the Coquihalla Connector at Loon Junction. The other subunits, presumed to occupy a slightly higher stratigraphic positions, comprise coextensive and contemporary stratigraphy that differ significantly in lithology and depositional setting. They consist of marine clastic deposits which cover a broad area in the east-central map area and, in the west, pass across a gradational contact into terrestrial conglomerate deposits.

The marine clastic unit generally weathers recessively and is mainly composed of layered sandstone and siltstone, rare thin limestone and minor pebble conglomerate locally containing notable tuffaceous components of crystal pyroclasts or ash-tuff laminae. Ultrapotassic basalt, distinguished by analcime phenocrysts, form discontinuous exposures rarely up to several tens of metres thick in the tuffaceous sandstone-siltstone unit. A major conglomeratic unit of undetermined thickness (Fairweather conglomerate, unit uTrNSHFscp) is widely distributed

west of Kentucky-Alleyne fault where it drapes the Iron Mountain formation. This unit, studied in detail and previously interpreted as lahars (Christopher, 1973; Lefebure, 1976) is mainly composed of subangular to rounded cobbles and boulders of Nicola mafic volcanic porphyries, and intrusive clasts of diorite and monzonite. Dacitic lithic tuff, and tuff resedimented as immature volcanic grit beds, form a discontinuous band several hundred metres wide (formerly called Zig unit of Mihalynuk et al., 2016) in the Fairweather conglomerate. Fine apatite, biotite and quartz derived

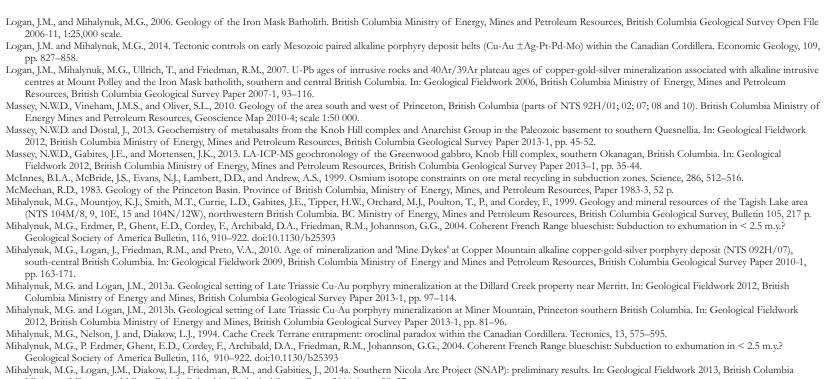
from tuff comprise a few percent to only trace amounts in these rocks, but are significant because of their broad dispersal throughout the Shrimpton formation, and as a mineralogic marker to establish contemporaneity of deposition between terrestrial and marine subunits. Geochronology from the Shrimpton formation includes: two U-Pb zircon samples, felsic tuffs in both terrestrial (~202 Ma)

and marine tuffaceous sedimentary units (~200 Ma), and U-Pb detrital zircons samples of which three are terrestrial rocks (<207, <202 and <201 Ma) and one is from shallow lagoonal facies (<204 Ma, with nearby, metre-thick limestone layer) and one is from marine strata interlayered with thin analcime basalt flows (<200 Ma; Fig. 4). The detrital zircon samples all favour Rhaetian stage as the maximum time of deposition. During this time, at least two vigorous felsic eruptions resulted in fallout of crystals and ash-size fragments, which settled in both terrestrial and marine environments. A U-Pb 202 Ma date is the older volcanic pulse which occurred within an interval of overall declining Nicola arc magmatism. This volcanism also corresponds with a marine incursion that resulted in submarine deposits onlapping those of the terrestrial arc margin. Thin limestones, calcareous black siltstone and tuffaceous siltstone in the marine section contain rare ammonoids of indeterminate age. A younger ash-bearing interval with conspicuous, discrete layers up to 3 cm thick returned a U-Pb age of ~ 200 Ma (Friedman et al., 2020). This earliest Jurassic age from topmost strata of the Nicola Group marks the culmination of Nicola arc evolution in

Nicola Arc-Slocan Basin Evolution

southern Quesnel terrane.

Nicola Group stratigraphy records Middle and Late Triassic magmatic arc development. At least one major unconformity is recognized in the Middle Norian suggesting a period of tectonic instability, and a magmatic hiatus that apparently lasted more than 3 million years. This unconformity effectively separates current lithostratigraphy of the Nicola Group into two developmental stages: a lower stage dominated by arc-building constructional episodes, and an upper stage of arc destabilization and a protracted interval of subaerial erosion and intermittent to waning arc magmatism. In this upper stage, the predominant arc-derived clastic deposits and accumulations of mafic volcanic rocks coalesce with marine deposits during a transgressive event that marks terminal deposition of the Nicola arc.



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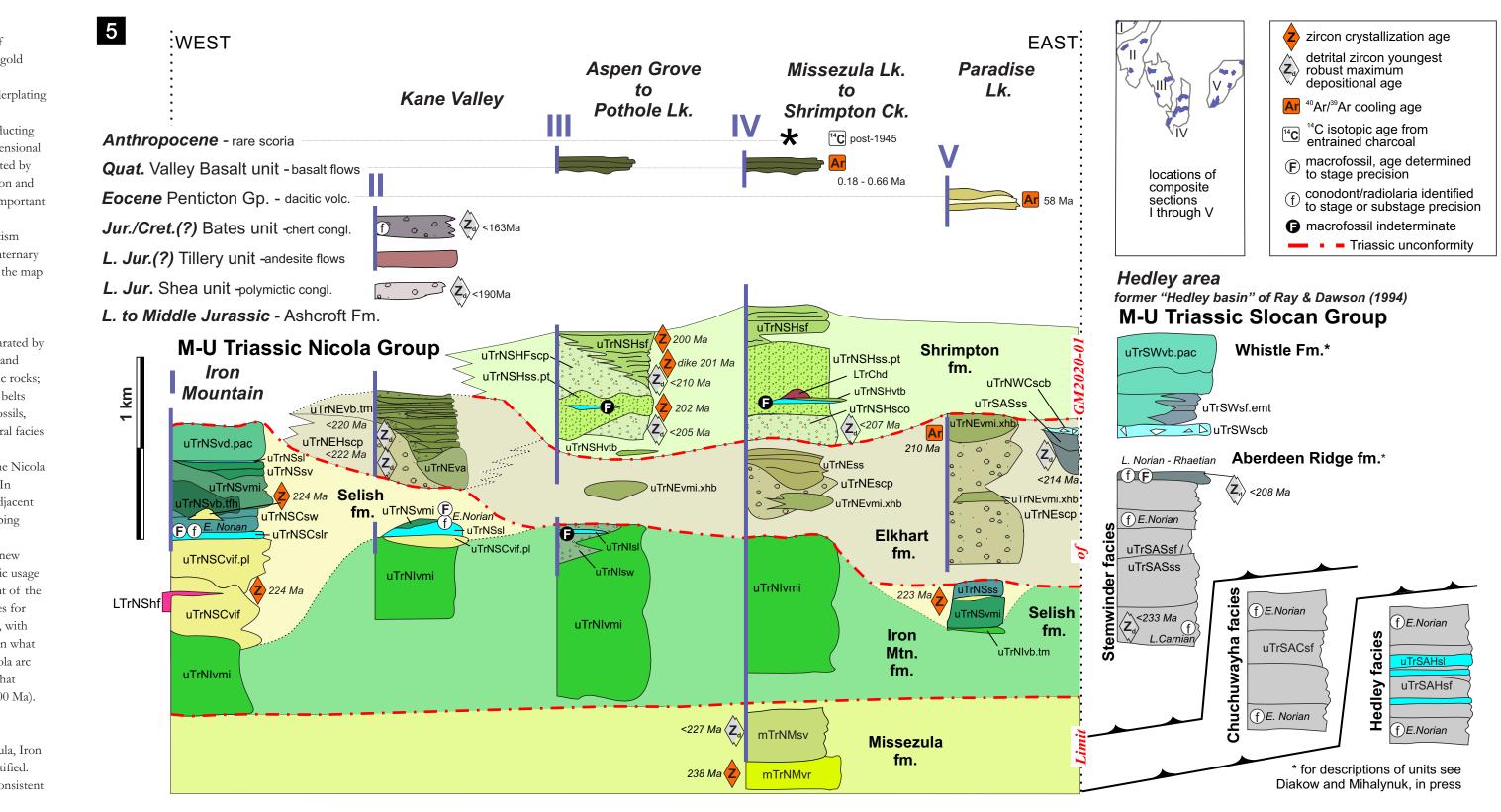
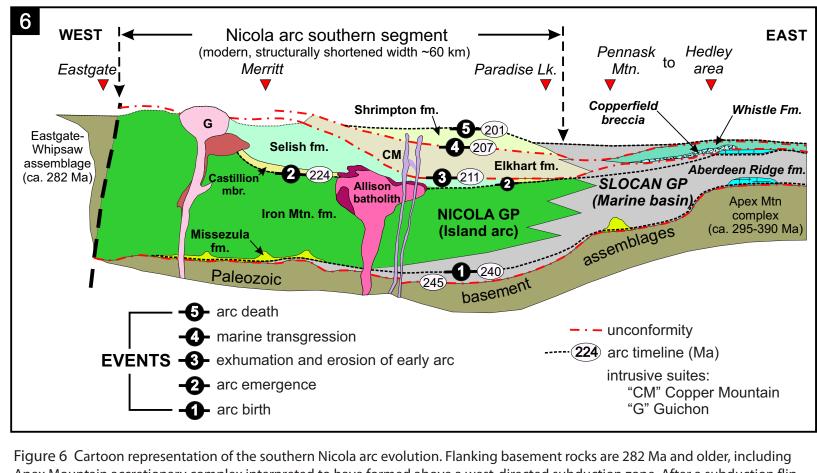


Figure 6. Comparative lithostratigraphy for subregions across the northern Geoscience Map 2020-01 area, as well as the Hedley area. Rapid lateral lithofacies changes typical of volcanic arc terranes are common. Age data that help to constrain correlations across the area are shown, as highlighted by background colours for formations within the Nicola Group. The same colours are used on the time stratigraphic chart of Figure 4. Missezula formation is projected from south of the Shrimpton Creek area, and contacts with overlying Iron Mountain formation, the main constructional phase of the Nicola arc, is an inferred thrust fault contact. Nicola arc matured

and grew to emerge above sea level. Felsic magmas were produced, as recorded by the Selish formation. In Late

Norian, a period of arc instability and incision is recorded by the partly subaerial western Elkhart and largely submarine eastern Elkhart formation. Arc collision may be responsible for the instability. Undated picritic basalts occur near this transition and overlying units of the Shrimpton formation include ultrapotassic flows containing analcime. Between ~205 and 200 Ma Shrimpton formation strata transition upsection and to the east from shallow to deeper water facies. Slocan Group strata in the Hedley area are isoclinally folded, extensively repeated by thrust faults, and contain abundant Precambrian detrital zircons. In contrast, Nicola Group is affected by mostly open folds, with thrust faults identified only locally, and Precambrian zircons are rare or totally absent.



Apex Mountain accretionary complex interpreted to have formed above a west-directed subduction zone. After a subduction flip, felsic Nicola arc construction began ~239 Ma, and Cache Creek subduction complex formed west of the Nicola arc. During the intervening time, offshore subduction formed the Kutcho-Sitlika arc between ~265 and 240 Ma. Interplay of these events suggests kinematic linkage (see Fig. 7).

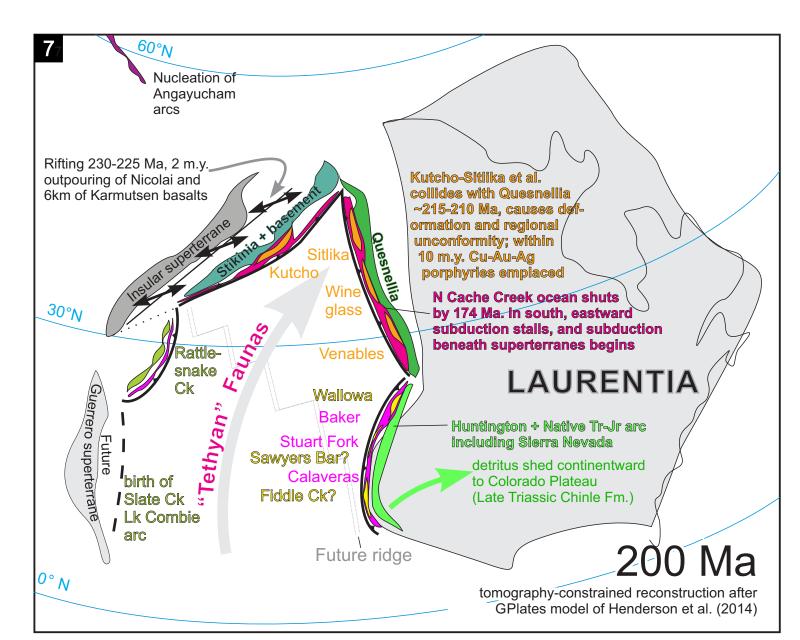


Figure 7. Cartoon at time of Nicola arc cessation ~200 Ma showing contemporary arc terranes in the United States. Arc-arc collision events ~210-215 Ma are thought to have caused rupture of the subducting plate, influx of hot asthenosphere and fusion of metasomatized mantle wedge (Fig. 8). Thus, Kutcho-Sitlika arc collision ~215-210 Ma may be key to forming the ~209-201 Ma porphyry belts in BC. Huntington arc in west USA displays similar ~210 Ma disruption, but without recognized porphyry deposits.

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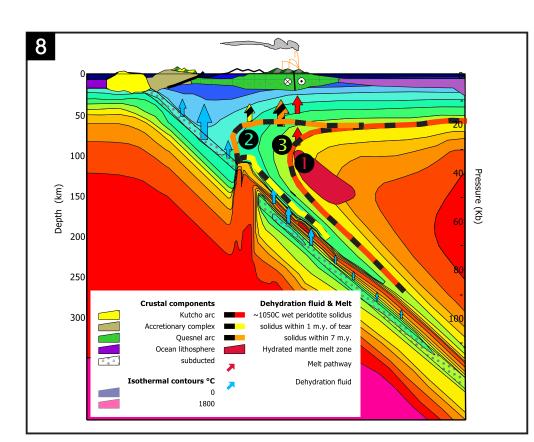
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Figure 8. Arc -arc collision events cause disruption of normal magmagenesis (1). Rupture of the subducting plate causes influx of hot subslab asthenosphere and ocused, high degree partial melting (2) as recorded in the arc by strongly alkalic and picritic units. As the thermal spike decays, widespread, low degree partial fusion of the metasomatized mantle wedge (3) liberating metal concentrated by dehydration fluids evolved from the subducting plate. Such events are envisaged for the Kutcho-Sitlika arc collision with Stikine - Quesnel (Nicola) arc ~215-210 Ma, forming the ~211-201 Ma porphyry belts in British Columbia (Fig. 3). Contemporaneous Huntington arc in the USA (Figs. 3, 7) displays similar ~210 Ma disruption, but no porphyries. Modified after Logan and Mihalynuk (2014).

Nicola arc development is coeval with upper Slocan Group which records extents of the 'Slocan sea' interpreted to onlap the ancient North American margin (e.g. Thompson et al., 2006). Earliest known sedimentary deposits of the Slocan Group are Anisian age (247.2 - 242 Ma from timescale of Cohen et al., 2013) previously included in Harper Ranch Group (Thompson et al., 2006); it is not until the Ladinian stage (~242 - 237 Ma) that depositional events recorded by Nicola strata and the Slocan Group begin to overlap, for 40 million years, from late Middle Triassic into earliest Jurassic. A reconstruction of Nicola arc paleogeography envisages an earliest episode in which bimodal volcanoes of the Missezula formation formed spaced, low relief cones or domes, possibly constructed atop old Paleozoic arc crust. This embryonic Nicola arc may have formed a line of volcanic centres that coalesce with marine clastic rocks at the western margin of the 'Slocan sea'. Existence of Precambrian detrital zircons of probable North merican provenance help in constraining the location of the 'Slocan sea' basin axis to east of the Nicola arc as no Nicola Group detrital samples analyzed thus far has revealed a Precambrian zircon. By Late Carnian into early Norian, established convergence and subduction of Cache Creek ocean produced robust mafic-intermediate eruptions that formed a continuous line of spaced submarine stratovolcanoes that regionally define

constructional stage of Nicola arc in the Middle Norian.

Contractional deformation Previous workers saw little evidence of contractional deformation, but major highway construction created outcrops in which thrust faults are well exposed. Projection of age contrainted strata establish older over younger relationships. Structural shortening affected the entire arc (Mihalynuk et al., 2015), possibly in two episodes, at ~214 to ~211 Ma, when a regional unconformity developed; and more clearly, between ~200 Ma (youngest Nicola Group strata with demonstrable thrust faults) and 194 Ma, the age of Pennask batholith (Parrish and Monger, 1992; Fig. 4) which cuts the deformed strata. Younger contraction, probably in the early Cretaceous, thrust Iron Mountain formation westward over the Bates conglomerate unit, and caused structural thickening and metamorphism of the western arc as exposed in the Tulameen River area. Evidence for lead loss or metamorphic overgrowth at 140 - 150 Ma that has been observed in a high proportion of detrital zircon samples may be related to this event. Some thrust faults may have been reactivated as extensional faults during the early Eocene, for example, during uplift of upper amphibolite facies metamorphic rocks in the Nicola Horst (Moore, 2000; Erdmer et al., 2002), about 10 km north of the map area (Fig.

Porphyry mineralization Two belts of Late Triassic porphyry mineralization are recognized in the southern Nicola arc (Figs. 2, 3; Logan and Mihalynuk, 2014): an older western calc-alkaline belt (Cu-Mo; e.g. Guichon Creek batholith), and relatively younger, eastern alkalic belt (Cu-Au-Ag ±Mo, Pd; e.g. Iron Mask batholith). An even younger belt (Early Jurassic) is to the east at the latitude of GM2020-01, includes the past-producing calc-alkaline Brenda deposit in the Pennask batholith (Fig.

Increasingly more precise geochronologic results from the Late Triassic Nicola porphyry belts have defined the age Close correspondence between the late Upper Triassic age of Nicola arc intrusions and the generation of porphyry wedge from hot subslab asthenosphere, the metal-enriched, metasomatized parts of the mantle wedge preferentially melted (Fig. 8) and generated protomagmas rich in chalcophile elements (e.g. Cu, Au, Pt, Pd; McInnes et al., 1999). By one estimate, porphyry mineralization formed during this collision event, a brief 6 m.y. centred at 205 Ma, produced >90% of the known copper resource in the Nicola Group of Quesnel terrane and coeval rocks in its sister, destabilization, uplift, and incision (~214 - 207 Ma), mineralization (209 - 201 Ma) and then dormancy, submergence and crustal shortening (201 - 196 Ma), is recorded in the geology of GM2020-01.

of calc-alkaline Guichon Creek suite (~215-207 Ma) with mineralizing phases and mineralization emplaced during the last ~2 m.y. between ~209 and ~207 Ma (Fig. ; Ash et al., 2007; D'Angelo, et al., 2017; Whalen et al., 2017). Located 20-30 km to the east, the belt of predominantly dioritic and monzonitic intrusions of the alkalic Copper Mountain suite are inherently more difficult to date. The most robust U-Pb data point to emplacement mainly between 205 - 201 Ma with mineralization dated throughout this span (Mortensen et al., 1995; Logan et al., 2007; Mihalynuk et al., 2010; Logan and Mihalynuk, 2014). Many small, undated dioritic intrusions (unit LTrCd) along the central axis of the map area are included in Copper Mountian suite, and some of these intrusions have related porphyry mineralization (Fig. 2). mineralization suggests some fundamental trigger in the arc system at this time. In accord with analogous environments (McInnes et al. 1999), thermodynamic calculations (Mungall, 2002) and computational geodynamic models (van der Zedde and Wortel, 2001), Logan and Mihalynuk (2014) proposed that destabilization of normal arc subduction led to generation of metal-laden melts in the mantle wedge between the subducting Cache Creek lithosphere and overlying Nicola arc. After ~30 m.y. of uninterrupted subduction and continuous devolatilization of subducted slab that metasomatized the overlying mantle wedge (Fig. 8), subduction was interrupted as the Cache Creek plate finally delivered the dormant Kutcho arc to the trench, clogging it (Fig. 7). This led to uplift of the Nicola arc, widespread unconformities, and rupture of the subducting slab. Without cold subducted lithosphere isolating the Stikine terrane (Logan and Mihalynuk, 2014). A compilation of the latest U-Pb and Re-Os age data from the southern Nicola arc (Fig. 4) changes the story little. Mineralizing intrusions were concentrated in a western calc-alkalic belt and an eastern, slightly younger alkalic belt over a span of ~8 m.y. from ~209 to 201 Ma. This mineralizing period followed a protracted stage of predominantly mafic arc construction and normal evolution of calc-alkalic arc crust sufficiently thick to generate granodioritic intrusions. An abrupt switch from normal arc growth ($\sim 239 - 214$ Ma) to

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the Nicola island arc in Quesnellia. In the SNAP area, phases of the composite Allison batholith may mark the roots of a mature stratovolcano responsible for the Iron Mountain formation with substantial thicknesses of maficintermediate breccia and flows extending for tens of kilometers. A less robust centre may have existed near the Coldwater pluton situated approximately midway between Merritt and the Allison batholith. West of Merritt, another volcanic centre may have developed, about midway between the magmatic centres represented by the Allison and Guichon batholiths. In this area, mafic strata of the Iron Mountain formation are onlapped by upper levels of Selish formation. However, an early transition from submarine to subaerial deposits is manifest in lowest Selish formation, the Castillion member. This distinctive interval is composed of multiple, subaerial volcanic layers alternating with fossiliferous limestone deposited as patch reefs that flourished on the periphery of this emerging volcanic centre. Interbedded welded tuff and limestone is evidence of sea level fluctuations. Welded tuff and accretionary lapilli tuff in successively higher intervals of the Selish formation establishes ongoing terrestrial deposition to the end of the early

Evidence for growth of Nicola arc between ~214 and 211 Ma is lacking. Neither sedimentary nor magmatic rocks have been recognized in the area of GM2020-01, and dated pulses of Guichon batholith (Whalen et al., 2017) extend the magmatic lull to the northwest. This interval corresponds with a regional unconformity (Logan and Mihalynuk, 2014) that presages a significant change in Nicola arc stability, further widespread uplift and erosion, and comparatively diminished magmatic activity during the upper developmental stage. This major unconformity is recognized in arc stratigraphy throughout Quesnel and Stikine terranes (Logan and Mihalynuk, 2014). By upper Norian renewed arc magmatism is recorded by intrusive activity in the Guichon batholith (~211 Ma) and Coldwater pluton (~210 Ma). Mafic-intermediate volcanic episodes are represented by hornblende-pyroxene phyric flows of the Elkhart formation $(\sim 210 \text{ Ma})$ and comparatively sparse plagioclase megacrystic flows that are localized as discontinuous accumulations within the mainly epiclastic facies. Erosion to subvolcanic levels along the arc axis is indicated from clast compositions that include a rich assortment of volcanic and intrusive lithologies, derived initially from Selish and Iron Mountain formations and the partly unroofed Allison batholith. Deeply oxidized clastic and interspersed volcanic rocks in these beds represent coalesced alluvial fan-like relics that draped older strata on an incised arc. Deposition of Elkhart clastic beds continued into Rhaetian, and by ~ 207 Ma another unconformity is marked by

coarse conglomerate grading up to finer clastic marine strata of the Shrimpton formation. Deposition of Shrimpton formation sand, silt and argillaceous strata containing sparse ammonites, signals a marine incursion onto the arc. Volumetrically minor volcanic beds occur in a minimum of two stratigraphic positions in terrestrial and marine lithofacies of the Shrimpton formation. Those of felsic composition and recognized by distinctive dispersed crystal or ash components, have been isotopically dated at ~200 Ma (Friedman et al., 2020) and record last gasps of the Nicola

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