Composite pericratonic basement of west-central Stikinia and its influence on Jurassic magma conduits: Examples from the Terrace-Ecstall and Anyox areas

JoAnne Nelson[1, a]

[1] British Columbia Geological Survey, Ministry of Energy and Mines, Victoria, BC, V8W 9N3
[a] corresponding author: JoAnne.Nelson@gov.bc.ca

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Abstract

The nature and affinity of the pre-mid-Paleozoic basement of Stikinia remains poorly known. However, this basement exerted a fundamental control on the location and distribution of intrusions and intrusion-related mineral deposits. A transect from west-central Stikinia near Terrace to the Ecstall belt (considered a possible correlative of the Yukon-Tanana terrane in the central Coast Mountains) indicates commonalities of basement; a comparison of detrital zircons from a Jurassic conglomerate (considered part of the Eskay rift) suggests that basement of central Stikinia differs from the Yukon-Tanana basement in the north.

Near Terrace, stratified upper Paleozoic and Mesozoic rocks of western Stikinia are cut by the Kleanza pluton, an ENE-elongate, multiphase Early Jurassic body. To the west, this section is juxtaposed with highly strained lower crustal rocks of the Central Gneiss Complex and Shames River intrusive complex (Early Jurassic) across the Shames River normal fault. Farther west, the Coast Shear zone marks the eastern boundary of the Ecstall belt, a mid-Paleozoic (in part Middle Devonian) magmatic arc complex cut by a Mississippian 'central diorite suite' and Early Jurassic plutons (Foch and Johnson). Geological continuity across the Terrace-Ecstall transect is demonstrated by similar igneous geochemical signatures of coeval Mississippian and Early Jurassic suites. Volcanic rocks of the Mt. Attree Formation and a small cogenetic pluton in the Terrace area are ca. 323-325 Ma (U-Pb zircon), somewhat younger than, but within error of, a previously published Mississippian age (336.8 ±17.7 Ma) from a pluton in the Ecstall belt. Both suites are silica bimodal, showing strong subduction influence in felsic rocks and non-arc immobile element signatures in metabasalts. Early Jurassic intrusive phases from all three areas show a continuum on modified alkali-lime, aluminum saturation and Fe* vs. silica plots, and generally increasing LREE/HREE and HREE/MREE with silica. Trace and major element chemistry show strong influence of plagioclase and hornblende fractionation. The Early Jurassic intrusions (ca. 200-180 Ma) are interpreted as having evolved in related magma chambers in a structurally controlled permeability corridor corresponding to the Skeena arch, which trends across the terrane at a high angle.

Late Early to Middle Jurassic stratified rocks on Mt. Clashmore, west of the Anyox deposit at the southern end of the Eskay rift, consist of basalt, rhyolite, and sedimentary rocks including monomictic breccias and cherty argillites with tuffaceous laminae. They are correlated with the Iskut River Formation of the Eskay rift in the Iskut region. Evenchick and McNicoll (2002) reported non-northwest Laurentian detrital zircons (1058-517 Ma) from a conglomerate at Mt. Clashmore that may have been derived from a fragment of accreted exotic pericratonic basement that was exposed in a horst or rift shoulder adjacent to the Eskay rift in the mid-Jurassic.

Rocks of the Ecstall belt and the cryptic Precambrian source of detrital zircons at Mt. Clashmore are parts of the composite, pre-late Paleozoic basement of Stikinia. Major long-lived (Late Devonian to Recent) N-S and E-W fault corridors in the terrane cut across different basement components, suggesting that their precursors formed after amalgamation of its basement but before or coeval with the oldest units in the Stikine assemblage.

Keywords: Stikinia, Stikine assemblage, Ecstall belt, Anyox, Mt. Clashmore, Eskay, Kleanza pluton, Jurassic

1. Introduction

Stikinia (Fig. 1) is a long-lived, multi-episodic, Devonian to Jurassic island arc terrane that extends for about 1000 km along the length of the Canadian Cordilleran orogen. Stikinia, Quesnellia (a similar multi-phase island arc), and other terranes such as Cache Creek make up the Intermontane terrane belt. These terranes developed in the northeastern Pacific peri-Laurentian realm (Nelson et al., 2013) before Middle Jurassic amalgamation and accretion to the continental margin. Stikinia hosts much of BC's copper, gold, and silver in Late Triassic to Middle Jurassic porphyry, epithermal, and VMS deposits, which formed during the latest episodes of arc activity and subsequent terrane amalgamation. Notable Mesozoic deposits (Fig. 1) include: porphyry Cu-Au at Red Chris mine, KSM, and Galore; porphyry Cu at Schaft Creek; epithermal Au at Brucejack and along the Premier-Stewart trend; and

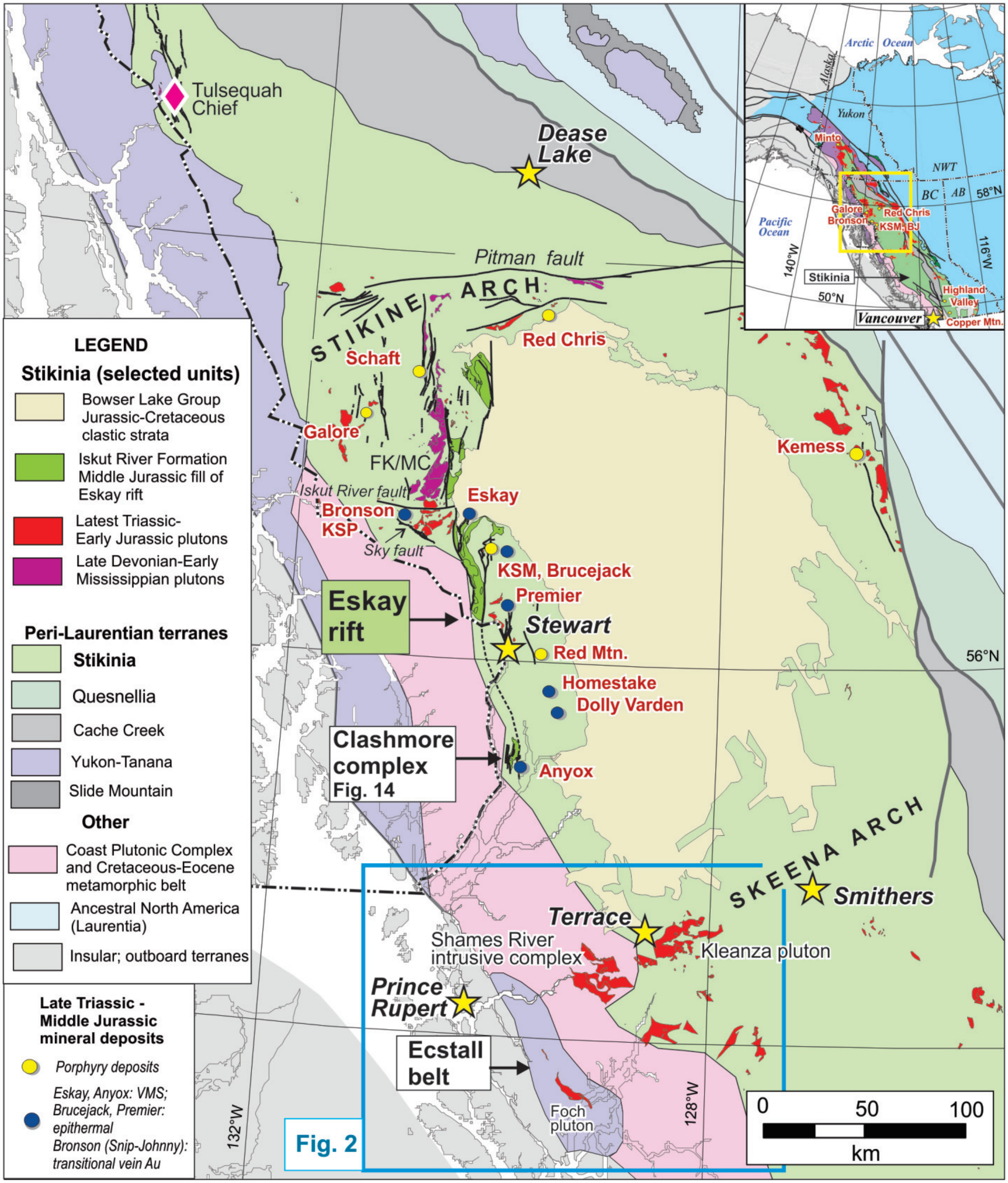

Fig. 1. Central and northern Stikinia. Long-lived, multiply reactivated N-S and E-W fault sets from Alldrick (2001). Selected map units from digital map of British Columbia (Cui et al., 2015) include latest Triassic-Early Jurassic intrusions, Devonian-Mississippian intrusive bodies, and the Middle Jurassic Iskut River Formation, which exhibit spatial and causative relationships to the major faults. FK/MC = Forrest Kerr and More Creek plutons.

volcanogenic massive sulphides at the Au-Ag-rich Eskay and Cu-rich Anyox mines (past producers) in the Eskay rift (Middle Jurassic). These and many related occurrences show spatial and, in many cases, genetic associations with major, long-lived and multiply reactivated N-S and E-W structural corridors (Nelson, 2014).

Prominent sets of northerly trending lineaments transect western Stikinia (Fig. 1). The N-S elongate Forrest Kerr-More Creek pluton (Late Devonian; Logan et al., 2000) and the NNW-trending Tulsequah Chief volcanogenic deposit (Late Mississippian) are the oldest features that show control by these faults (Nelson, 2014). The Eskay rift, a north-trending, 300 km-long, complex graben, formed over a brief period (ca. 178-174 Ma) coincident with collision of Stikinia and inboard Cache Creek terrane (Mihalynuk et al., 2004) and probably the outboard Insular terranes (Nelson et al., 2013). East of the rift, the KSM-Brucejack deposits show structural control by Early Jurassic basin-bounding transcurrent faults (Nelson and Kyba, 2014). A major fault in this system was later remobilized as the Sulphurets thrust during mid-Cretaceous sinistral transpression of western Stikinia; it forms the immediate hanging wall of the KSM porphyry deposits (Kirkham and Margolis, 1995; Evenchick, 2001).

Stikinia also contains westerly fault and lineament sets, the Pitman fault system along the Stikine arch, the Iskut River fault and Skeena arch structures (Fig. 1). In the north, the Pitman fault system marks an apparent northern limit to a prominent set of northerly structures of central-western Stikinia (Fig. 1), although cross-cutting relationships are not observed. The Red Stock, the ca. 204 Ma body that hosts the Red Chris porphyry deposit, is along the Boundary fault (Rees et al., 2015), a minor ENE-striking structure that is part of the Pitman array. The Pitman fault array coincides with the Stikine arch, a long-lived paleogeographic high at a high angle to the long axis of Stikinia (Fig. 1). Farther south, the Iskut River fault (Fig. 1) interrupts, and may offset, the faults bounding the Eskay rift (Alldrick, 2000). Early Jurassic Au vein and porphyry deposits of the Bronson-KSP camp developed between the Iskut River fault and the Sky fault (WNW striking), which underwent syn-mineral dextral-normal displacement (Kyba and Nelson, 2015). In the far south, the Skeena arch, a long-lived ENE paleogeographic high in central Stikinia near Smithers and Terrace, marks the southern edge of Bowser basin (Jurassic-Cretaceous), and hosts a swarm of Eocene plutons (Babine intrusions). The Kleanza pluton (Early Jurassic; 200-180 Ma) was emplaced along faults parallel to the axis of the Stikine arch (Figs. 1, 2; Nelson et al., 2008).

The northerly and westerly fault and lineament sets shown on Figure 1 are characteristic of, and are apparently confined to, Stikinia. They appear to have exerted strong spatial and, in many cases, genetic control on mineral deposits, by creating conduits for magmas and hydrothermal fluids. Long reactivation histories suggest that they reflect fundamental discontinuities in the pre-mid-Paleozoic basement of Stikinia, but the nature and affinity of this basement remains poorly known. Increased knowledge of Stikinia's basement will aid in understanding of the origin of these fundamental lineaments.

The oldest rocks exposed in the terrane, the Stikine assemblage and its correlatives, are Devonian and younger. The oldest known unit is a fossiliferous Emsian limestone west of the Forrest Kerr pluton (Logan et al., 2000). This may point to a subjacent crustal infrastructure thick enough to support shallow-water conditions in the Early Devonian, but the nature and lateral extent of such crust is unknown. Juvenile isotopic signatures from that part of Stikinia are inconsistent with the presence of pericratonic crust (Samson et al., 1989), as is the absence of Precambrian cores in zircons recovered from the Forrest Kerr-More Creek pluton (Late Devonian; Logan et al., 2000), compared to their abundance in coeval plutons of the Yukon-Tanana terrane. In contrast, near Tulsequah Chief in far northern Stikinia (Fig. 1), Devonian-Mississippian strata rest unconformably on, and pass transitionally into, pericratonic rocks of the Boundary Ranges suite (Mihalynuk et al., 1994; Mihalynuk, 1999; Currie and Parrish, 1997). The Boundary Ranges suite is continuous to the north with the Yukon-Tanana terrane of Yukon and eastern Alaska, a large peri-Laurentian terrane that rifted from the western North American margin during Late Devonian back-arc extension (Nelson et al., 2006a). The belt of pericratonic rocks in the Coast Mountains of southeastern Alaska has also been correlated with the Yukon-Tanana terrane (Gehrels et al., Pecha et al., 2016), although contrasting Precambrian detrital signatures and Ordovician-Silurian magmatism in SE Alaska suggest significant differences between the two. The difference between evolved basement character in northern Stikinia and juvenile basement character in central Stikinia could reflect either primary heterogeneity or pre-Late Devonian amalgamation of oceanic and pericratonic terranes.

Direct observation of potential basement components of Stikinia is generally difficult. High-grade metamorphism, intense deformation, and extensive Cretaceous and Eocene plutonism of the Coast Mountains orogen obscure most of the western edge of the terrane, where the deepest exposures occur and possible links to pre-Devonian pericratonic strata might be preserved. Fieldwork in 2016 was designed to evaluate proposed links between Stikinia and terranes to the west, taking advantage of two areas in which evidence for connection between Jurassic rock units of Stikinia and pericratonic fragments to the west have been identified by previous workers.

In this paper I first examine a transect across the Coast Mountains orogen from Terrace to Prince Rupert (Figs. 1, 2). This transect crosses from Stikinia in the east, through the Central Gneiss Complex, which includes metamorphosed Early Jurassic intrusive rocks (Heah, 1991), and through the Ecstall belt, a Yukon-Tanana correlative intruded by Mississippian and Early Jurassic plutons that Gareau (1991) and Gareau and Woodsworth (2001) recognized as common with Stikinia. Our work focused primarily on geochronologic and geochemical sampling of Early Jurassic intrusive bodies and late Paleozoic intrusions and comagmatic volcanic rocks. Some of the

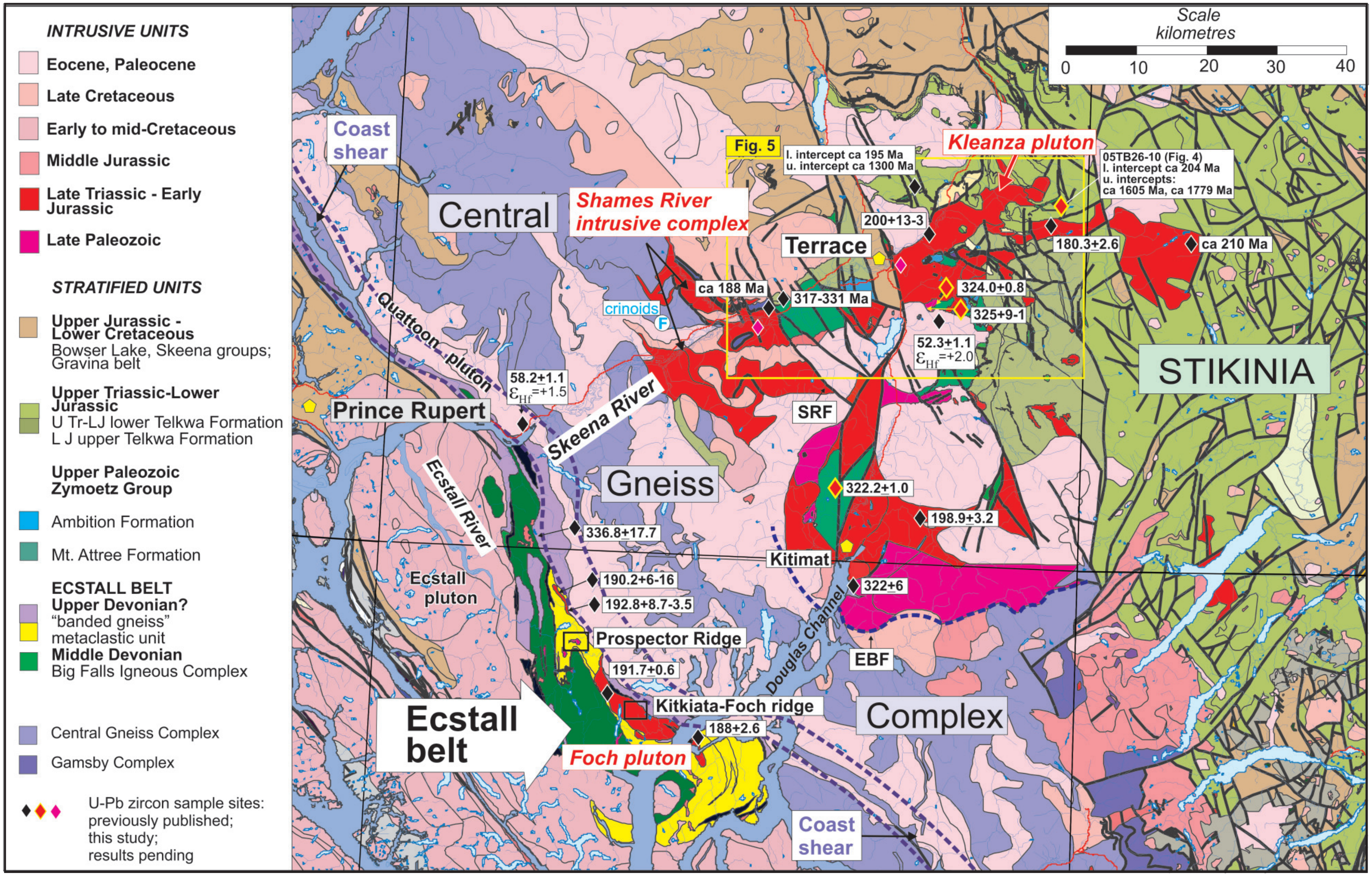

Fig. 2. Geology of Stikinia and the adjacent Coast Mountains orogen in the Terrace-Prince Rupert area (Cui et al., 2015). U-Pb ages from Heah (1991), Gareau et al. (1997) Gehrels et al. (2009), and this study. Selected ε_{Hf} values from Cecil et al. (2011). EBF = Eastern bounding fault of Central Gneiss Complex (Rusmore et al., 2005), SRF = Shames River fault (Heah, 1991). Crinoid locality from Hill (1985). 2016 traverses in the Ecstall belt covered northern Prospector Ridge and Kitkiata-Foch ridge areas. See Figure 1 for regional context.

geochronologic work is ongoing, but this paper presents four previously unpublished U-Pb ages from the Terrace area.

I then examine a Toarcian-Bajocian volcanosedimentary succession near Mt. Clashmore on the western flank of the southern Eskay rift, near Anyox (Fig. 1). This conglomerate has yielded a limited suite of detrital zircons with non-northwest Laurentian Precambrian ages (Evenchick and McNicoll, 2002), pointing at an unknown pericratonic source that contributed sediment to the rift. Mapping of the Mt. Clashmore area supported recollecting detrital zircon samples from the conglomerate reported by Evenchick and McNicoll (2001).

2. Terrace-Ecstall transect

2.1. Regional geology

Paleocene and Eocene faults divide the area between Terrace and the Ecstall River into three structural-tectonic domains: western Stikinia, the Central Gneiss Complex, and the Ecstall belt (Figs. 2, 3). Near Terrace on the east, upper Paleozoic through Lower Cretaceous strata of Stikinia and the Kleanza pluton (Early Jurassic) are bound by the Shames River normal fault (Eocene; east-side-down). To the west, in the core of the Coast Mountains orogen, polydeformed amphibolite- to granulite-grade rocks of the Central Gneiss Complex are structurally overlain by the Shames River mylonite zone, which Heah (1991) interpreted as an early Tertiary east-side-down low-angle detachment. It comprises interleaved panels of Early Jurassic granitic rocks (Shames River orthogneiss), paragneiss probably equivalent to that in the main Central Gneiss Complex, and ca. 69 Ma syntectonic plutons. The Coast shear zone forms the boundary between the Central Gneiss Complex and the Ecstall belt farther west (Fig. 2). It is a steep, generally east-side-up dextral-reverse fault (Hollister and Andronicus, 2000) with a strike length over 1200 km (Rusmore et al., 2001). The Quottoon pluton (Paleocene) was emplaced during motion on the fault (Rusmore et al., 2001). The Ecstall belt consists of Middle to Upper Devonian arc-related metavolcanic and metasedimentary strata of arc and pericratonic affinity, intruded by Late Mississippian (ca. 336 Ma) and Early Jurassic (ca. 191-193 Ma) plutons (Gareau and Woodsworth, 2000; Alldrick et al., 2001). It is considered part of the belt of Yukon-Tanana equivalents in the Coast Mountains (Gareau and Woodsworth, 2000; Pecha et al., 2016).

The section of stratified rocks near Terrace is typical of Stikinia overall. Upper Paleozoic volcanic rocks of the Mt. Attree Formation and small cogenetic intrusions are overlain by richly fossiliferous Permian limestones of the Ambition Formation (Nelson et al., 2008). This sequence, the Zymoetz Group, is equivalent to the Stikine assemblage farther north (Nelson et al., 2008). Above the limestone, the Stuhini Group comprises an unusually thin (<50 m) unit of dark grey to black Upper Triassic chert and argillite. Uppermost Triassic-Lower Jurassic volcanic-rich rocks of the Telkwa Formation (Hazelton Group) unconformably overlie the older rocks, and are in turn overlain by upper Hazelton strata, including the Red Tuff Member of the Nilkitkwa Formation and the Smithers and Quock formations (Barresi et al., 2015). Upper Jurassic to Lower Cretaceous strata of the Bowser Lake Group form the top of the succession. The Kleanza pluton intrudes as high as the upper part of the Telkwa Formation. Igneous ages of ca. 204, ca. 193-195 and ca. 178 Ma from volcanic rocks (Gareau et al., 1997; Barresi et al., 2015) show a roughly similar range to two Kleanza samples at 200 +13/-3 Ma and 180.3 ±2.6 Ma (Gareau et al., 1997; Gehrels et al., 2009). Although complicated by numerous high-angle faults, the Terrace stratigraphic section youngs progressively to the east (Fig. 2), suggesting prevailing eastward dips. As is the case in most of Stikinia, the nature of the basement is not directly known. Precambrian lower crustal domains are hinted at by zircon inheritance in a Telkwa Formation rhyolite near the northeastern end of the Kleanza pluton (Figs. 2, 3, this study; see below). Gareau et al. (1997) reported Mesoproterozic inheritance (ca. 1300 Ma) from an Early Jurassic unit 25 km to the west (Fig. 2). Zircon from an Eocene intrusion southeast of the Kleanza pluton shows an unusually low ε_{Hf} value of +2.0, indicative of old continental crust (Cecil et al., 2011; Fig. 2). Precambrian domains cannot be extensive, because isotopic signatures are mostly juvenile and most igneous zircon populations lack inherited components.

The Central Gneiss Complex remains one of the most enigmatic rock units in the Cordillera. Consisting of Cretaceous orthogneiss and older paragneiss and orthogneiss, it represents the roots of the Coast Mountains arc as it evolved between 90 and 45 Ma (Rusmore et al., 2005). Rocks of the Central Gneiss Complex underwent recumbent folding and kyanite- and sillimanite-grade metamorphism, followed by as much as 28 km (8.5 kb) of early Tertiary exhumation (Rusmore et al., 2005). Low-angle detachment faulting along the Shames River mylonite zone and its southern equivalent near Douglas Channel, the Eastern Boundary detachment fault (Fig. 2), played an important role in this unroofing (Rusmore et al., 2005). The hanging wall of the detachment comprises subgreenschist- and greenschist-grade rocks of Stikinia, which formed part of the upper crustal load during Cretaceous metamorphism. The Shames River 'orthogneiss' is a layered mafic to intermediate meta-intrusive complex that forms extensive panels in the Shames River mylonite zone (Fig. 2). It has yielded a U-Pb zircon multi-grain age of 188 ±8 Ma (Heah, 1991), which falls within the latest Triassic-Early Jurassic range of ages for the Kleanza pluton and Telkwa Formation. The Shames River intrusive complex is a potential deep-level equivalent of the Kleanza pluton, decapitated by the early Tertiary detachment system (Fig. 3). Cretaceous-Tertiary tectonic burial-exhumation has largely obscured evidence for protoliths and tectonic affinity of the pre-plutonic gneisses. Although detailed isotopic data are lacking, most plutons intruding the complex have juvenile $\varepsilon_{Hf}(t)$ signatures (+10.2 - +15.1), indicating minimal interaction with old crust (Cecil et al., 2011). A calc-silicate paragneiss north of the Skeena River contains well-preserved large crinoid fragments (Fig. 2; Hill, 1985), similar to those in the Ambition Formation near Terrace. Based on similar juvenile crustal signatures, structural juxtaposition, and lack of a major

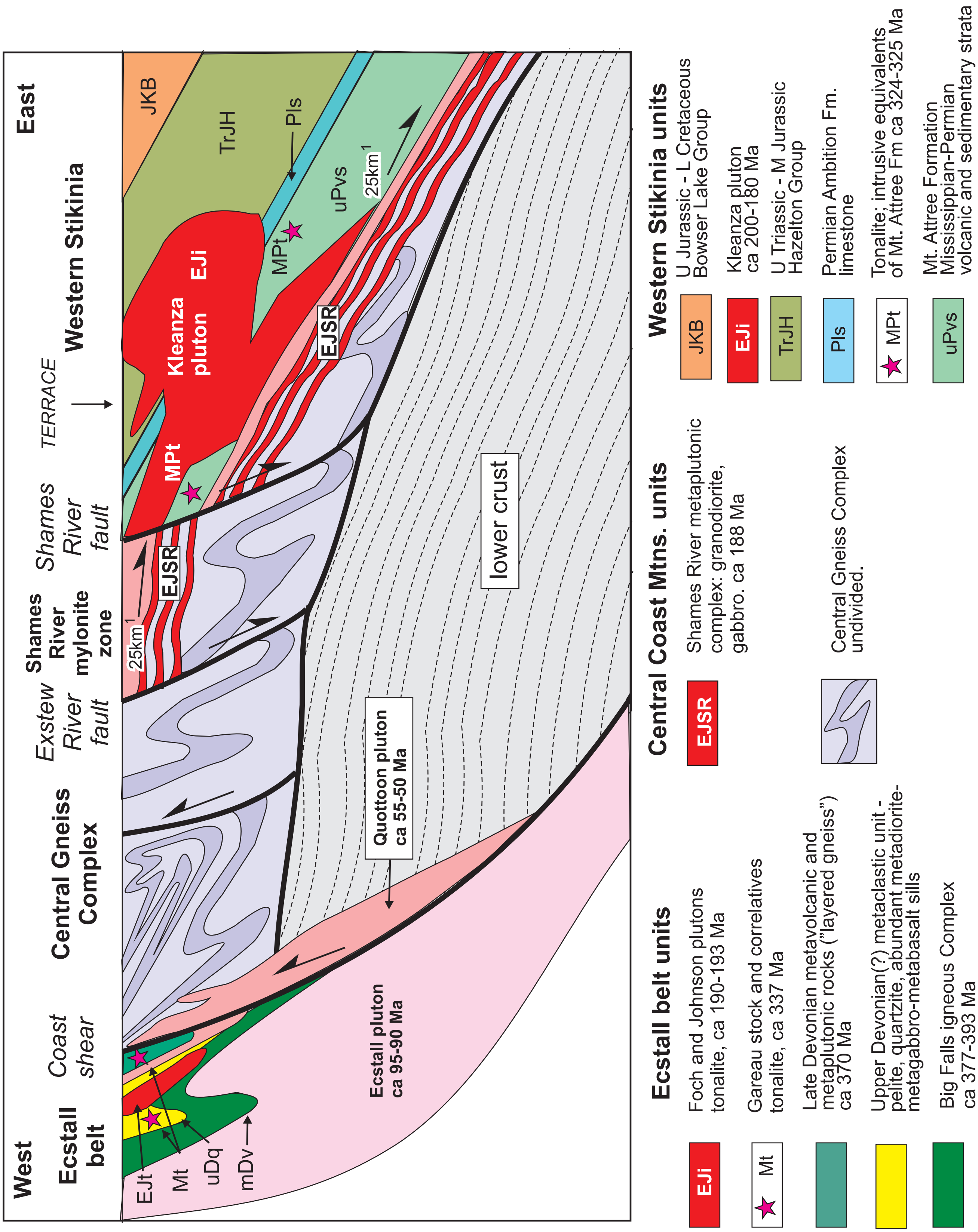

Fig. 3. Schematic east-west crustal cross-section of Stikinia and the eastern and central parts of the Coast Mountains orogen, approximately along the Skeena River. General relationships from Heah (1991), Hollister and Andronicos (2000), Angen (2009). [1]Estimated displacement on Shames River mylonite zone from Heah (1991).

intervening suture, the Central Gneiss Complex is thought to be basement (infrastructure) to Stikinia (Cecil et al., 2011).

The Ecstall belt (Alldrick 2001; Alldrick et al., 2002), also referred to as the Scotia-Quaal belt (Gareau and Woodsworth, 2000) is a tightly folded, amphibolite facies metavolcanic-metaplutonic-metasedimentary package. Metavolcanic and metaplutonic rocks of the Big Falls igneous complex, the stratigraphically lowest unit in the belt, have 377 to 393 Ma (Middle Devonian) U-Pb zircon ages (Alldrick et al., 2001). It hosts several significant volcanogenic massive sulphide prospects. A regionally extensive unit of quartz-rich metaclastic strata (Figs. 2, 3) overlies the volcanic unit. It consists of a lower dark grey to black meta-siltstone with interlayers of granite clast-bearing conglomerate, and an upper white to light grey quartzite (meta-sandstone) with micaceous partings (Alldrick 2001). The metaclastic unit is overlain by metavolcanic 'layered gneiss', which yielded a Late Devonian, ca. 370 Ma U-Pb zircon age (Alldrick et al., 2001; Gareau and Woodsworth, 2000).

A small, weakly foliated quartz diorite stock that intrudes the layered gneiss is 336.8 +17.7/-7.1 (Gareau, 1991). Similar bodies in the belt (Central diorite suite) are correlated with this mid-Mississippian pluton (Fig. 2; Alldrick et al., 2001; Alldrick et al., 2002). Two Early Jurassic plutons, the Johnson Lake equigranular tonalite (ca. 193-190 Ma) and the Foch Lake plagioclase-megacrystic tonalite (ca. 192 Ma), cut units and early foliation of the belt (Gareau and Woodsworth, 2000). These plutons may constitute a link with Stikinia, in which intrusions of this age are common (Gareau and Woodsworth, 2000; Alldrick, 2001). Other features of the Ecstall belt have led to correlations with pericratonic rocks in the Yukon-Tanana terrane (Gareau and Woodsworth, 2000). The Big Falls complex (Middle Devonian) and its volcanogenic deposits have been compared to the Finlayson assemblage of Yukon-Tanana terrane, although their ages differ by 20-30 million years (380-390 Ma vs. 352-360 Ma; Nelson et al., 2006a). Limited ε_{Nd} data from metaclastic rocks are -1.5 to -4.5 (Gareau and Woodsworth, 2000). An ε_{Hf} (t) value of -1.5 in ca. 58 Ma zircons from the Quattoon pluton in the Coast Shear Zone near the northern end of the Ecstall belt reflects significant incorporation of old continental crust (Cecil et al., 2011). The abundance of metaclastic quartzites in the Ecstall belt and evolved isotopic signatures suggest that it may have formed as an arc in continental margin setting similar to, but older than, Late Devonian-Early Mississippian (370-345 Ma) arc development in the main Yukon-Tanana terrane of Yukon and east-central Alaska (Nelson et al., 2006b). Early Middle to Late Devonian (393-370 Ma) igneous ages in the Ecstall belt overlap Silurian-Devonian (428-365 Ma) ages in the Endicott Arm assemblage, the middle unit of the Yukon-Tanana terrane in southeast Alaska (Pecha et al., 2016).

2.2. New geological, geochronological and geochemical data

Two igneous suites, late Paleozoic and Early Jurassic, may be common to Stikinia near Terrace and the Coast Mountains orogen. Geochronologic and geochemical data from our study will aid in comparing these suites. Below I present four previously unpublished U-Pb zircon data sets, three from Late Paleozoic units in the Terrace-Kitimat area, and one from a Telkwa rhyolite. Analyses are pending for two geochronologic samples, collected in 2016, from the Kleanza pluton near Terrace and a Shames River complex granodiorite. Geochemical samples of Early Jurassic intrusive bodies are from the Kleanza pluton, its unnamed extension along the Skeena River west of Terrace, the Shames River meta-intrusive complex, and the Foch pluton on Kitkiata-Foch ridge in the Ecstall belt. Late Paleozoic units were sampled for geochemistry on Prospector Ridge, along the Skeena River west of Terrace, and in the Williams Creek valley southeast of Terrace.

2.2.1. Late Paleozoic units

Volcanic and metavolcanic rocks of the Mt. Attree Formation form the oldest and most westerly exposures of stratified rocks in the western Stikinia domain (Figs. 2-4; Nelson et al., 2008; Nelson, 2009). Before this study, a single Permian U-Pb zircon age of 285 ±9 Ma was obtained from these rocks (Gareau et al., 1997). Small tonalitic plutons intrude the sequence in Williams Creek southeast of Terrace (Fig. 4) and on Mt. Clague, northwest of Kitimat (Fig. 2). Except for the single fossiliferous marble (see above), Paleozoic protoliths are not recognized in the Central Gneiss Complex. In the Ecstall belt, a group of small diorite and tonalite intrusions (Central diorite suite) cut older stratified units (Alldrick, 2001; Alldrick et al., 2001). A pluton of this suite yielded a ca. 336 Ma age (Gareau, 1991; Alldrick et al., 2001). Late Paleozoic supracrustal rocks are not exposed in the Ecstall belt, presumably because of deep erosion to Devonian strata.

U-Pb TIMS zircon data from samples collected in 2007 and 2008 document late Paleozoic ages for the pluton in Williams Creek and a dacite tuff in the Mt. Attree Formation near Kitimat (Figs. 2, 4; see Nelson and Friedman, 2017 for full data and analytical techniques). A small tonalite pluton cuts the Mt. Attree Formation on the north side of Williams Creek, 8 km southeast of Terrace. It is quartz-rich, varying from equigranular to quartz- and plagioclase-phyric, and well-foliated (Fig. 5a). Original mafic minerals are recrystallized to smears of biotite and ragged actinolite. Intrusive contacts with surrounding metavolcanic rocks are partly overprinted by foliation. Both the pluton and the Mt. Attree Formation are crosscut by fresh, unfoliated granodiorite of the Kleanza pluton. Of two samples from this body, 07JK17-09 yielded a well-constrained age of 324.0 ±0.8 Ma from five concordant grains (Fig. 6a). The other, 07JA05-01, shows more complicated systematics and probable lead loss, with an estimated age of 325 +9-1 Ma (Fig. 6b). An inlier of well-foliated, greenschist-grade metavolcanic rocks outcrops in the valley north of Kitimat and on the lower slopes of Mt. Clague (Fig. 2). A sample of pale green dacite with lavender-blue opaline quartz phenocrysts (Fig. 5b), 08JN01-03, gave an age of 322.2 ±1.0 Ma, based on a weighted average of three concordant grains.

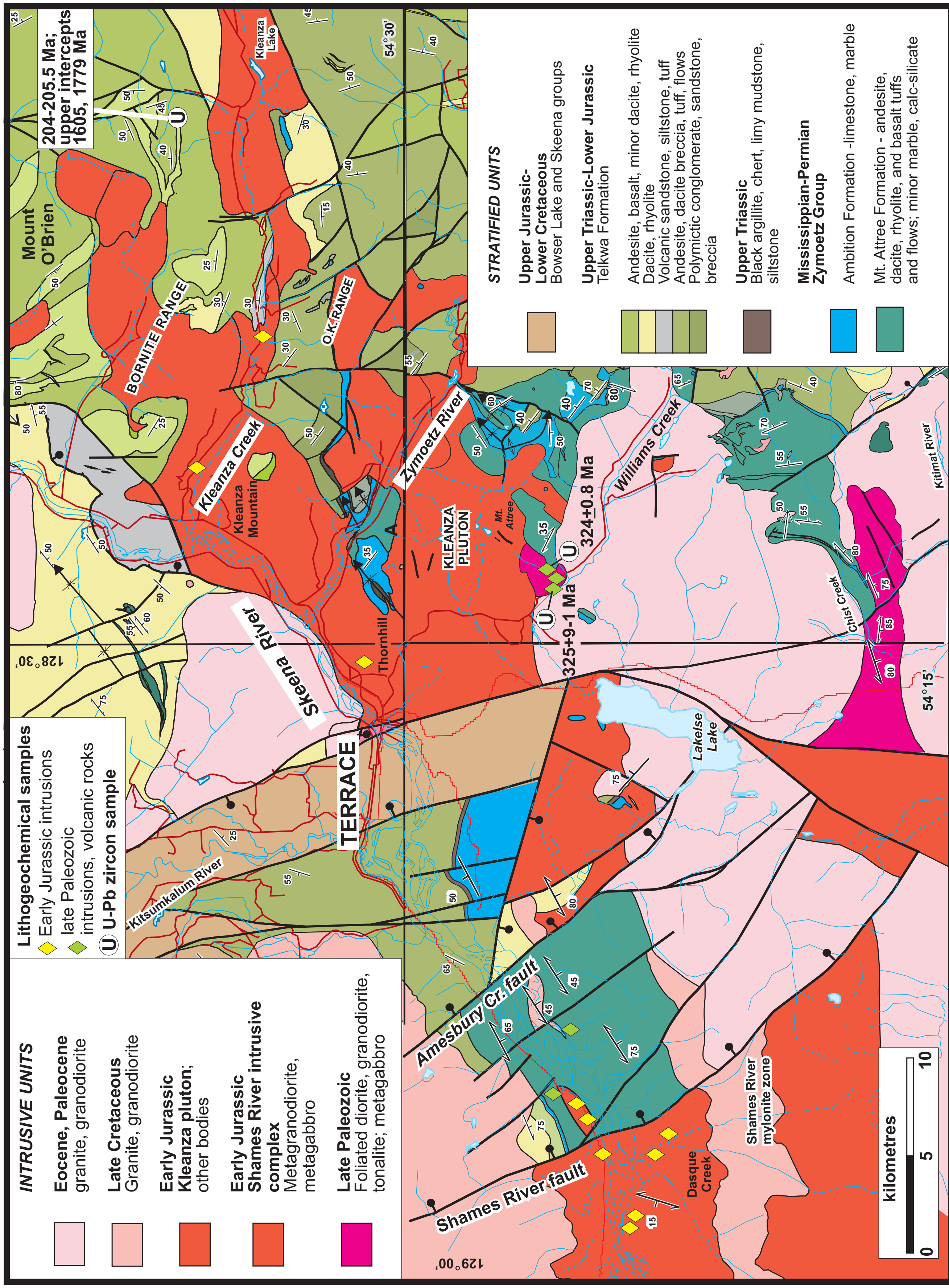

Fig. 4. Geology of western Stikinia and eastern Coast Mountains orogen near Terrace, with locations of U-Pb geochronological and lithogeochemical samples presented in this paper.

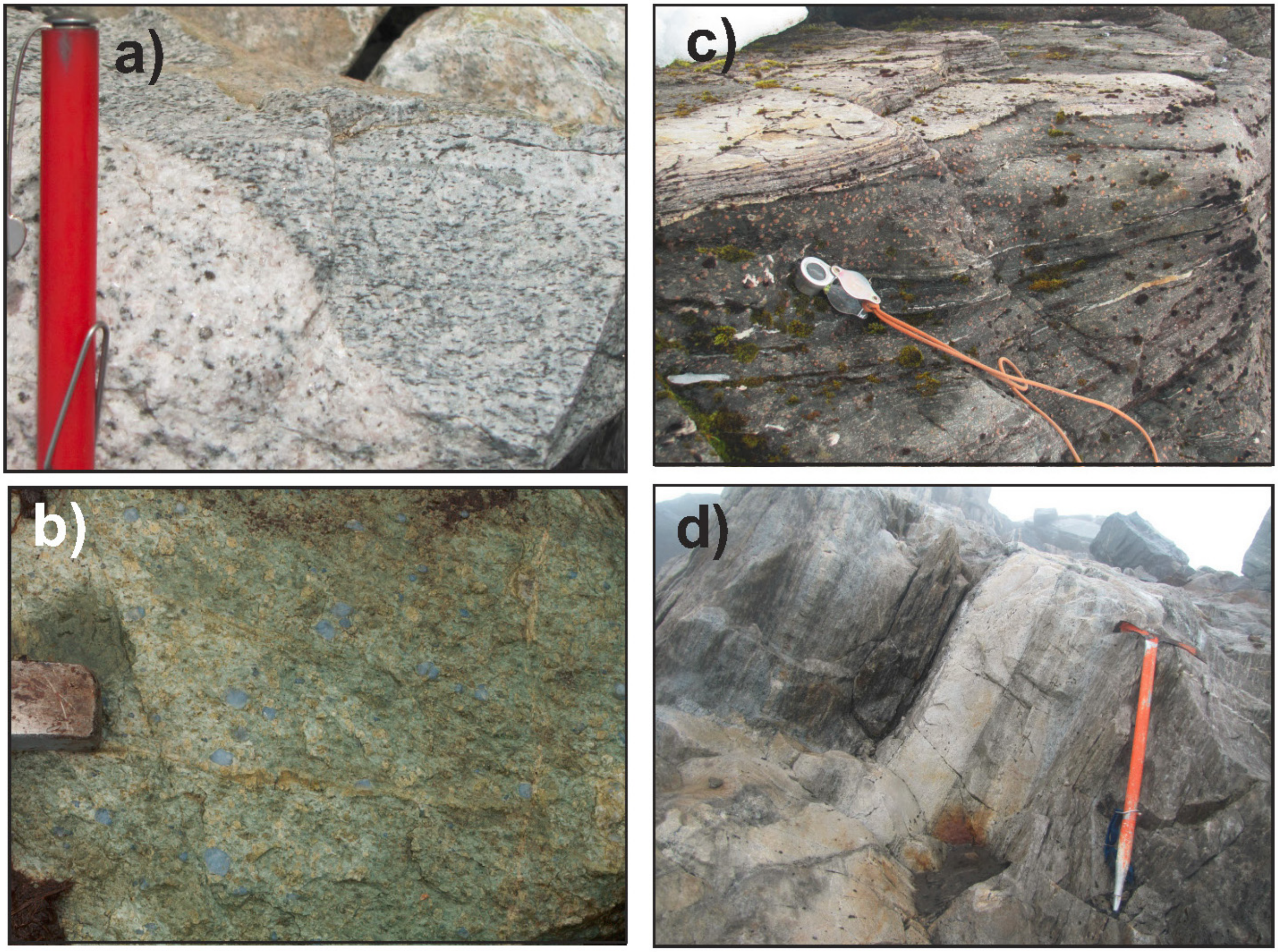

Fig. 5. Photos of Paleozoic units. **a)** Well-foliated metatonalite, Williams Creek, at U-Pb sampling site 07JA05-01, cut by fresh, unfoliated Kleanza granodiorite dike, 535436 E, 6031818 N. **b)** Opaline quartz-eye dacite, west of Kitimat, 07JN05-08, 517824 E, 5993220 N. **c)** Garnet amphibolite in contact with layered quartz-rich metaclastic schist, northern Prospector Ridge, 16JN01-04, 470628 E, 5967336 N. **d)** Metatonalite with leucotonalite sill, northern Prospector Ridge, 16JN03-04, 470991 E, 5966833 N.

All three ages coincide within error, indicating a significant ca. 325-322 Ma volcanic-intrusive event close to the Mississippian-Pennsylvanian boundary. They overlap the intrusive ages of 331-317 Ma reported by Heah (1991) along the Skeena River, and 322 ±6 Ma reported by Rusmore et al. (2005) near Kitimat (Fig. 2). Because of large errors, the 336.8 ±17.7 Ma age of the Gareau stock in the Ecstall belt also overlaps this cluster.

In 2016, a suite of nine late Paleozoic samples were collected for whole rock and trace element analysis, including two dacites and a metabasalt of the Mt. Attree Formation, three tonalites from the pluton in Williams Creek, two tonalites and a diorite from the ‘Central diorite suite’ on Prospector Ridge, and two garnet amphibolite dikes or sills that cut the Upper Devonian(?) metaclastic unit, also on Prospector Ridge (Table 1; see Nelson and Friedman, 2017 for full geochemical data and analytical techniques).

On northern Prospector Ridge, sill-like garnet amphibolite bodies form metre- to decimetre-thick layers that alternate regularly with quartz-rich metaclastic schists (Fig. 5c). Contacts are sharp and, in some cases, the mafic units cross-cut transposed compositional layering in the schists. These bodies are interpreted as sills or completely transposed dikes. Most are uniformly fine grained, and are probably metabasalts. Remnant intrusive textures are present in a few zones, including unfoliated plagioclase-hornblende intergrowths and acicular hornblende-bearing mafic pegmatites. An inhomogeneous felsic body, mainly pale brownish tonalite with leucotonalite sills (Fig. 5d) and mafic enclaves, intrudes both the mafic and surrounding metaclastic rocks.

The Paleozoic suite shows clear bimodality on Harker-type, X vs. SiO_2 plots, with the basalt and garnet amphibolite samples at <50% SiO_2 and the dacites and tonalites at 65% to 75% SiO_2 (Figs. 7, 8). The suite plots within the calc-alkalic to calcic field (Fig. 7) on the Modified Alkali-Lime Index vs. SiO_2 plot of Frost et al. (2001). On a Fe* vs. SiO_2 plot (Fig. 8), it is entirely magnesian; typical of magmatic arc rather than

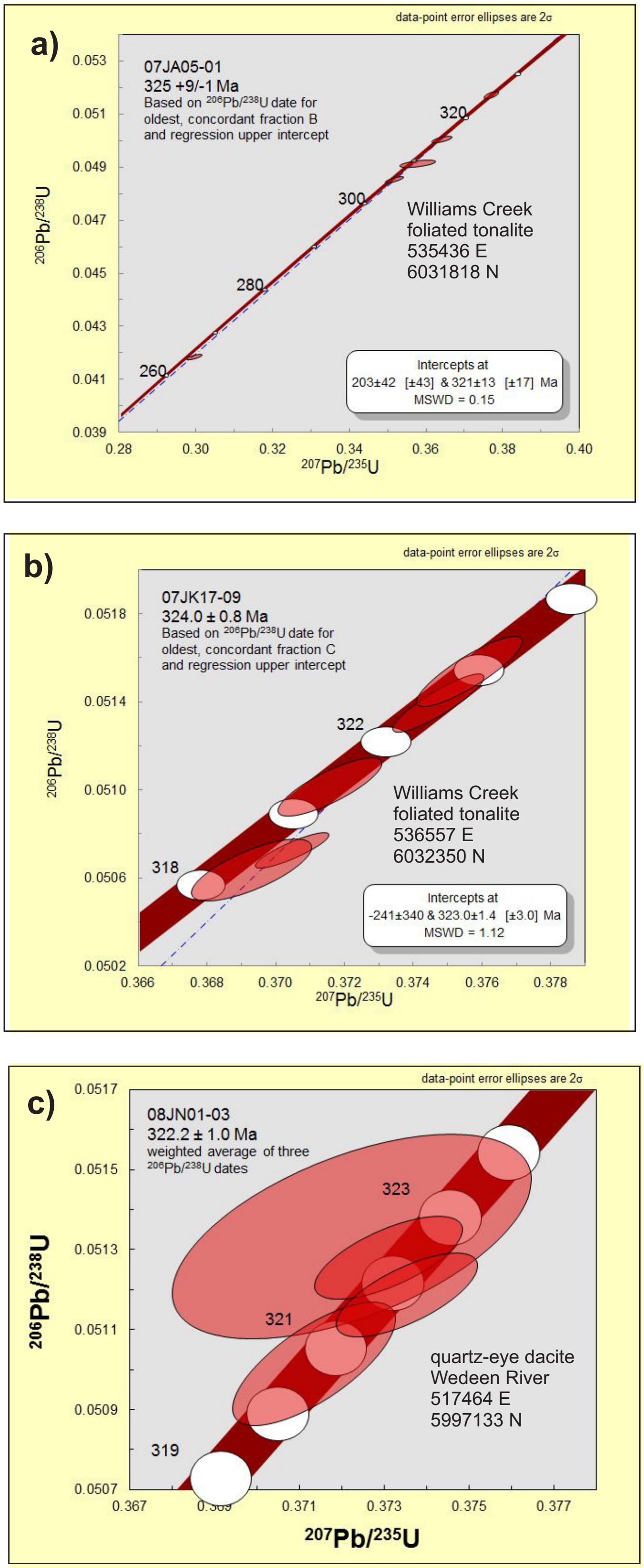

Fig. 6. Concordia plots for Paleozoic units.

A-type affinities (Frost et al., 2001). The mafic rocks show overall enrichment in immobile trace elements normalized with respect to primitive mantle, and smooth, uniform profiles that characterize non-arc igneous rocks (Fig. 9a). The Ecstall garnet amphibolites display slight negative REE slopes and Nb enrichment characteristic of enriched mid-ocean ridge basalts (E-MORB), whereas the Mt. Attree metabasalt has a flat REE profile and slight negative Nb anomaly typical of back-arc basin basalts (BABB; Piercey et al., 2006). In contrast, profiles for all the felsic rocks show relative depletions in Nb, Ti, V, and Sc which typify subduction-related signatures (Figs. 9b-d). All but one sample (16JN14-01, a quartz-eye dacite south of the Skeena River) display negative REE slopes and significant Th enrichment, all features of calc-alkaline suites. Compared to those from the Ecstall belt, the Stikinia tonalite samples show similar to greater Nb and Ti troughs, lower Sm, and higher Al. The Ecstall and Williams Creek (Stikinia) tonalites differ in absolute abundance of HREE, with a somewhat higher level in the Ecstall pluton. This implies a difference in the REE enrichment of the mantle source area.

In summary, U-Pb ages from the late Paleozoic igneous suites in Stikinia and the Ecstall belt overlap, ranging from Middle Mississippian to lowermost Pennsylvanian. Both suites are bimodal, with coexisting non-arc-derived mafic and calc-alkaline felsic magmatism. Mt. Attree Formation mafic rocks are of back-arc basin affinity, whereas those from the Ecstall belt are E-MORB. The Ecstall felsic samples show overall greater enrichment of REE, particularly LREE. The similar ages and geochemistry of these two suites suggest general consanguinity. However, systematic differences suggest separate magma sources and/or processes of magma evolution.

2.2.2. Early Jurassic intrusive and extrusive bodies

Early Jurassic intrusions occur throughout the transect, from the Kleanza pluton and its correlatives in western Stikinia, through the Shames River orthogneiss of the central Coast Mountains orogen, to the Foch and Johnson plutons in the Ecstall belt (Fig. 2). They thus represent a potential link between Stikinia and the older assemblages to the west, and more specifically may have crystallized at different crustal depths within a series of interconnected magma chambers. Sampling in 2016 concentrated on the Early Jurassic bodies to test these hypotheses. Five geochemical samples were collected from the Kleanza pluton and correlatives along the Skeena River west of Terrace, five from the Shames River suite, and five from the Foch Lake pluton. Two geochronological samples were collected to address current knowledge gaps and will be reported on elsewhere: a granodiorite of the Thornhill phase of the Kleanza pluton from a roadside outcrop along Highway 37 just south of its intersection with Highway 16 (16JN18-06); and a granodiorite from the Shames River intrusive suite near Dasque Creek south of the Skeena River (16JN14-03; Table 1).

Table 1. Descriptions of lithogeochemical samples shown on Figures 8, 9, 10, 12, 13.

Station	UTM E	UTM N	Area	Map unit	Age	Rock name	Description
16JN01-01	470295	5967536	Ecstall belt - Prospector Ridge	sill in quartz metaclastic unit	Late Paleozoic	garnet amphibolite	In meta-arenite and meta-pelite.
16JN01-03	470476	5967481	Ecstall belt - Prospector Ridge	sill in quartz metaclastic unit	Late Paleozoic	garnet amphibolite	Concordant with layering in metaclastic unit. Areas of metadioritic texture (sill or transposed dike).
16JN03-04	470991	5966833	Ecstall belt - Prospector Ridge	central diorite complex	Mississippian	metatonalite	Equivalent to Gareau stock. Metatonalite-metadiorite-metaleucotonalite; layered.
16JN03-07	471396	5967033	Ecstall belt - Prospector Ridge	central diorite complex	Mississippian	metadiorite	Salt and pepper medium- to fine-grained metadiorite; same body as sample 16JN03-04.
16JN03-08	471300	5966976	Ecstall belt - Prospector Ridge	central diorite complex	Mississippian	metadiorite/ tonalite	Slabby metadiorite or tonalite, hb-qz-plag with leucotonalite layers. Same unit as 16JN03-04.
16JN18-01	535429	6031827	Williams Creek	unnamed pluton	Mississippian	tonalite/ granodiorite	07JA05-01, ca 323 Ma foliated granitoid, tonalite-granodiorite. 30% plag, 10% Kspar, 15% qz, 20% hb, bi; 25% irresolvable matrix.
16JN18-02	535873	6031778	Williams Creek	unnamed pluton	Mississippian	tonalite	Tonalite, well foliated, fine-med grained, small mafic xenoliths. 45% plag, 35% qz, 20% bi (some secondary after hb). Same body as sample 16JN18-01.
16JN18-03a	536405	6032082	Williams Creek	unnamed pluton	Mississippian	tonalite	Tonalite, same body as sample 16JN18-01
16JN14-01	512716	6030900	Skeena River	Mt. Attwood Formation	Late Paleozoic	dacite	Metadacite, blue quartz eyes, pale green, aphanitic matrix.
16JN16-07	509371	6031627	Skeena River	Mt. Attwood Formation	Late Paleozoic	dacite	Plag-quartz-phyric dacite with some blue quartz eyes. 40% plag, 10% qz, 5% hb, 5% bi, 30% aphanitic matrix. Near Heah's (1991) 317-331 Ma U-Pb sample.
16JN18-03b	536405	6032082	Williams Creek	Mt. Attwood Formation	Late Paleozoic	metabasalt	Metabasalt in contact with tonalite
16JN05-03	483415	5953006	Ecstall belt	Foch pluton	Early Jurassic	metatonalite	Coarse-grained metatonalite, 50% plagioclase .5-1 cm, 20% quartz, 25% smaller hb, trace tit, ga, ep, msc
16JN05-07	484225	5951404	Ecstall belt	Foch pluton	Early Jurassic	metadiorite	Salt and pepper metadiorite, border phase of Foch pluton
16JN05-10	484307	5951316	Ecstall belt	Foch pluton	Early Jurassic	metadiorite	Salt and pepper metadiorite, border phase of Foch pluton
16JN06-01	483367	5953468	Ecstall belt	Foch pluton	Early Jurassic	metatonalite	Metatonalite, relatively mafic-rich. 42% plagioclase, 25% quartz, 30% hb, 3% biotite, tr tit, ep, ga.
16JN07-04	483123	5956367	Ecstall belt	Foch pluton	Early Jurassic	Plagioclase porphyry	Metatonalite/metagranodiorite, well layered, near pluton margin. Plagioclase phryric.

Table 1. Continued.

Station	UTM E	UTM N	Area	Map unit	Age	Rock name	Description
16JN13-02	493493	6032977	Exstew River	Shames River intrusive complex	Early Jurassic	Tonalite(?)	Fine-grained tonalite, well foliated. 35% quartz, 25% plag, 30% hb, 10% bi, tr mt.
16JN13-03	491801	6032777	Exstew River	Shames River intrusive complex	Early Jurassic	gabbro	Hornblende-rich gabbro, spaced well foliated and unfoliated panels.
16JN14-02	507286	6025714	Dasque Creek	Shames River intrusive complex	Early Jurassic	gabbro	Powerhouse outcrop; layered coarse gabbro, black amphibolite, leucotonalite. Gabbro is 60% hb, 25% plag, 5% qz, 10% bi, tr py.
16JN14-03	506759	6026369	Dasque Creek	Shames River intrusive complex	Early Jurassic	granodiorite	Foliated granodiorite, 50% plag, 25% qz, 15% bi, 3% hb, .5% mt., trace titanite.
16JN14-05	502442	6027963	Dasque Creek	Shames River intrusive complex	Early Jurassic	tonalite	Tonalite, medium-grained, equigranular, well foliated and lineated. 40% plag, 39% qz, 23% hb, 5% bi, 2% mt.
16JN14-06	502482	6027731	Dasque Creek	Shames River intrusive complex	Early Jurassic	granodiorite	Granodiorite, strongly foliated, protomylonitic. 35% plag, 25% qz., 15% Kspar, 15% hb., 8% bi, 2% mt.
16JN16-01	506497	6029206	Shames River	Shames River intrusive complex	Early Jurassic	tonalite	Heah's (1991) classic outcrop, ca 188 Ma U-Pb zr sample site. Interlayered mafic and felsic intrusive rock, protomylonitized. Tonalite 40% plag, 25% qz, 25% bi, 8% hb, 2% mt.
16JN12-01	531934	6042021	Terrace	Kleanza intrusive suite	Early Jurassic	granodiorite	Thornhill phase of Kleanza pluton. Unfoliated, cliff-forming granodiorite, 30% plagioclase, 30% quartz, 20% Kspar, 10% hornblende, 5% biotite.
16JN15-01	540649	6050285	Kleanza Creek	Kleanza intrusive suite	Early Jurassic	granodiorite	Medium-grained granodiorite, 25% quartz, 25% plagioclase, 15% Kspar, 35% hornblende.
16JN15-03	548117	6046651	Kleanza Creek	Kleanza intrusive suite	Early Jurassic	microdiorite	Crowded porphyritic (pl-hb) microdiorite. 40% plag, 7% hb., 3% ep, 3% py, 1% mt, 46% dark microcrystalline matrix.
16JN16-03	508226	6029924	Skeena River	Kleanza intrusive suite	Early Jurassic	granodiorite	Granodiorite, moderately well foliated. 35% plag, 30% qz., 15% hb, 10% bi, 10% Kspar. Good candidate for transition from Shames River to Kleanza.
16JN16-04	508920	6030302	Skeena River	Kleanza intrusive suite	Early Jurassic	hornblende diorite	Hornblende diorite, related to granodiorite of 16-3 but with characteristic texture of felted acicular hb. Weak, sporadic foliation developed in epidote metazones.

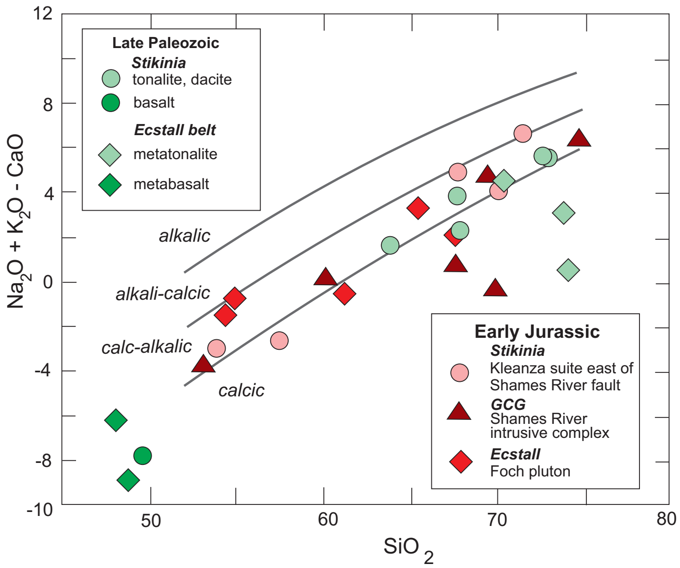

Fig. 7. Paleozoic and Early Jurassic samples on a MALI (modified alkali-lime vs. silica) plot of Frost et al. (2001).

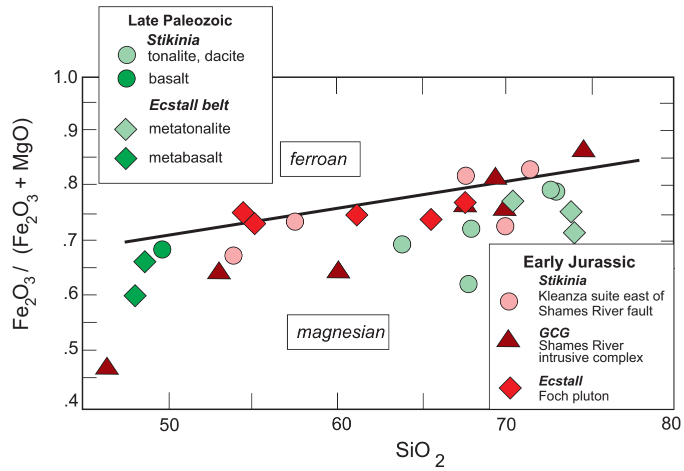

Fig. 8. Paleozoic and Early Jurassic samples on a Fe* vs. silica plot of Frost et al. (2001).

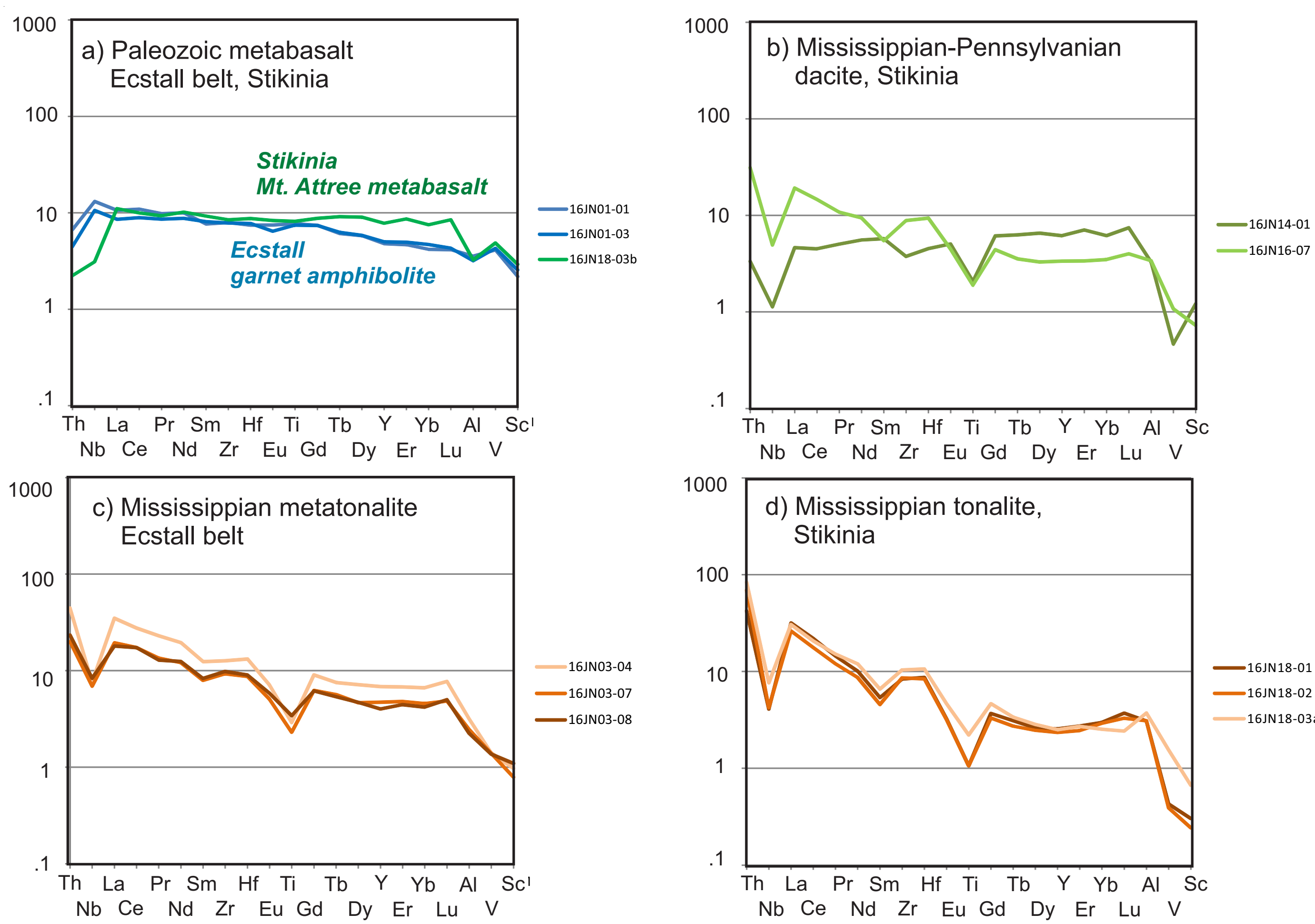

Fig. 9. Spider plots of immobile trace elements for Paleozoic samples, normalized against primitive mantle values of Sun and McDonough (1989). Choice and order of elements from most to least compatible after Piercey et al. (2006).

2.2.2.1. Kleanza plutonic suite

Coarse-grained, moderately- to weakly-foliated diorite and granodiorite cut deformed late Paleozoic metavolcanic and metaplutonic rocks along the Skeena River west of Terrace. The main Kleanza pluton extends in three lobes up to 40 kilometres east-northeast from Terrace, including the prominent cliffs north of Thornhill (Fig. 10a). It comprises many phases of differing composition and texture. Coarse-grained, equigranular to K-feldspar-megacrystic granodiorite and granite (Fig. 10b) predominate in its southern and western exposures, from Mt. Thornhill to Kleanza Mountain, cutting the upper part of the Zymoetz Group and lower Telkwa Formation. The ca. 200 Ma U-Pb age (Gareau et al., 1997) is from a highway cut in this phase. North and east, higher-level, porphyritic diorite and monzonite phases are in the Bornite Range; on Mt. O'Brien, subvolcanic andesite passes transitionally to ca. 195 Ma flows of the upper Telkwa Formation (Nelson et al., 2006b; Barresi et al., 2015). This overall pattern is interpreted to signify post-emplacement eastward tilting of the pluton along with its stratified hosts. Coarse-grained, pink quartz-rich granite and monzogranite occur in the Kleanza Creek drainage. Gehrels et al. (2009) reported a ca. 181 Ma U-Pb zircon age from near Kleanza Lake. Minor muscovite occurs in the granite near the U-Pb sample site. Because these granites represent a distinct, significantly younger phase compared to most of the Kleanza pluton, they are not included in the geochemical study.

2.2.2.2. Shames River intrusive complex

The Shames River intrusive complex outcrops extensively at low elevations west of the Shames River fault (Fig. 2). Although termed an 'orthogneiss' by Heah (1991), its compositional variations are primary rather than metamorphic; therefore the term 'intrusive complex' is preferred. Phases range in composition from hornblende gabbro to diorite, tonalite and granodiorite. Some bodies are homogeneous over several square kilometres. Rafts of mafic xenoliths occur near the margins of more felsic bodies (Fig. 10c). In some outcrops, well-foliated and sheared tonalite/granodiorite and gabbro bodies are interlayered on a metre to decimetre scale (Fig. 10d). Inter-phase contacts are sharp, and textures in both mafic and felsic components are igneous rather than gneissic. These bodies are interpreted as transposed sill complexes. They may occur in parts of the complex that have undergone higher ductile strain. Shear sense indicators in them show normal-sense (top-to-east) displacement (Heah, 1991; this study).

2.2.2.3. Foch pluton

The Foch pluton is a 5 by 25 km, northwest-elongate tonalite body that intrudes stratified metavolcanic and metaclastic rocks of the Ecstall belt. Compared to the strong transposition fabric of its hosts, it is variably foliated. Sparse metamorphic garnet indicates that it went through the same Cretaceous garnet amphibolite-facies metamorphism as the older rocks of the Ecstall belt. Primary minerals include plagioclase, quartz, hornblende, biotite, and varying amounts of magnetite. Textural and compositional variations in the main pluton are gradational. It is cut by leucotonalite (trondhjemite) dikes (Fig. 10e). The main phase ranges from coarse grained equigranular to plagioclase-megacrystic (Fig. 10f). Rafts of mafic xenoliths occur rarely (Fig. 10g). In a few cases, trains of shape-oriented plagioclase megacrysts parallel mafic schlieren, indicating magmatic flow. Fine-grained diorite occurs locally at the edge of the intrusion. The Foch pluton is much more homogeneous then either the Kleanza suite or the Shames River intrusive complex. Its plagioclase megacrystic textures are unique.

Numerous planar, fracture-controlled epidote-quartz zones cut the pluton (Fig. 10h). Some are cored by narrow, planar quartz veins. The zones tend to localize foliation and shearing (Fig. 10h). In some, small garnets developed at the expense of epidote. These zones probably formed during late stage cooling of the pluton. Because of the original fracture control and abundance of fine-grained secondary hydrous minerals, they likely focused strain during Cretaceous deformation. These low-temperature post-magmatic zones suggest that the Foch pluton was emplaced at fairly shallow depths in the upper crust, and does not represent the deep root of an Early Jurassic magma chamber. The pluton, along with older stratified rocks of the Ecstall belt, was tectonically buried and metamorphosed under garnet amphibolite facies conditions in the Cretaceous.

2.2.2.4. Geochemistry

A set of 17 samples was submitted for major and trace element analysis (Table 1; see Nelson and Friedman, 2017 for full geochemical data and analytical techniques). Given that the Early Jurassic suites are primarily coarse-grained plutonic rocks, geochemical interpretation focuses on major element chemistry for classification and comparison (see Frost et al., 2001). Trace element signatures give approximate evidence of tectonic setting, but must be interpreted with caution because of likely extensive fractionation and possible multi-phase melting.

On the Modified Alkali-Lime Index (MALI) vs. silica diagram (Fig. 7), most samples from the three Early Jurassic suites plot as a single continuous sequence within or just below the calc-alkalic field. Two samples from the Shames River intrusive complex are more calcic. On the Fe* vs. silica diagram (Fig. 8), the combined suite shows a progression from magnesian to weakly ferroan at highest contents of SiO_2, a pattern typical of Cordilleran granites (Frost et al., 2001). Figure 11 shows Aluminum Saturation Index vs. silica for the suite, which plots as a narrow, single trend from metaluminous to weakly peraluminous at highest contents of SiO_2. This pattern resembles that of the Tuolumne pluton in the Sierra Nevada, a typical differentiated Cordilleran calc-alkalic continental arc intrusion (Frost and Frost, 2014). In all three Harker-type (X vs. silica) diagrams, some Shames gabbros are the lowest in SiO_2, and Foch tonalite analyses plot in the centre of the wide range of silica values of Kleanza and Shames samples. This is consistent with the relatively homogeneous intermediate character of the Foch pluton, as opposed to the great compositional and textural

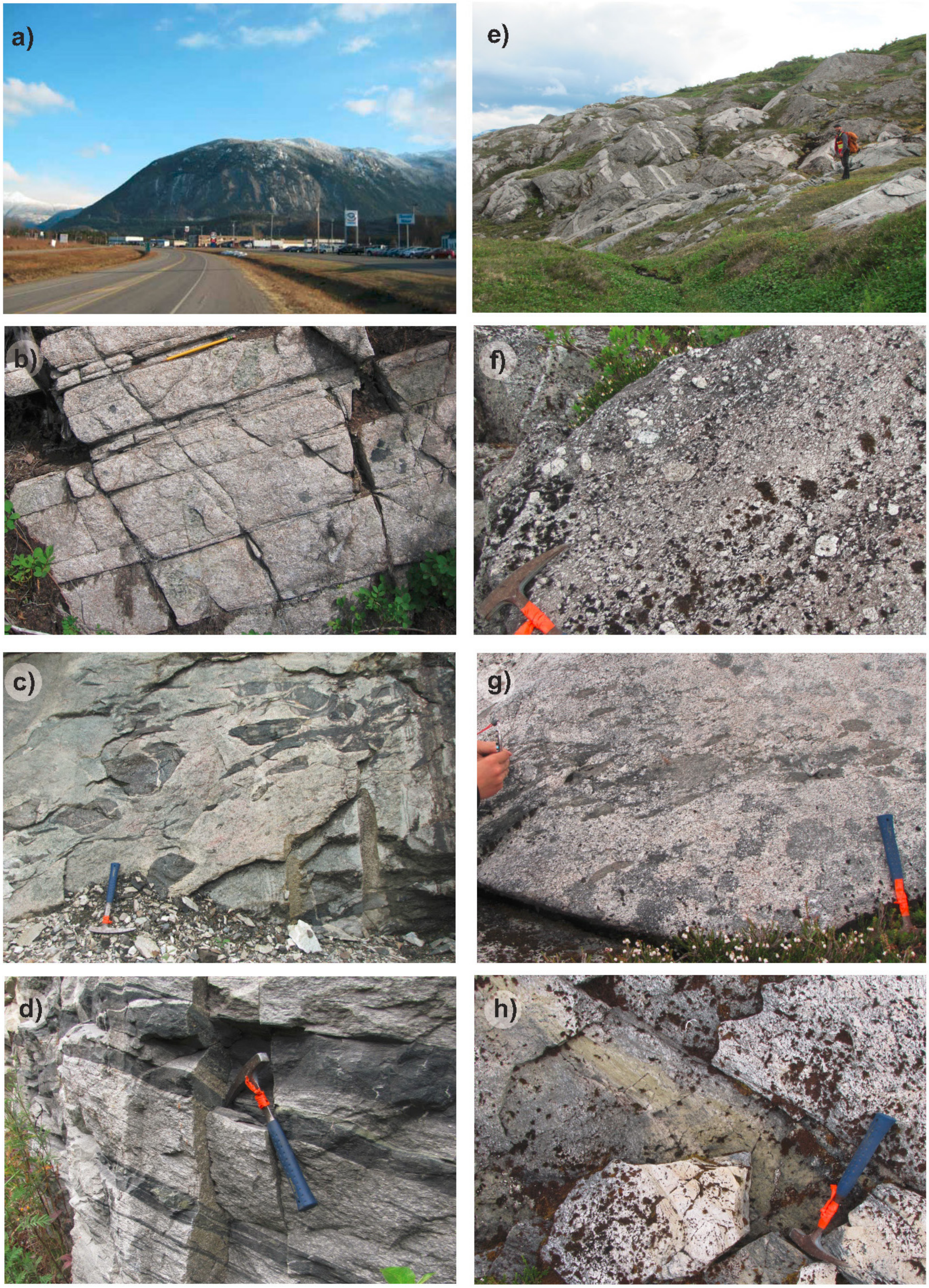

Fig. 10. Early Jurassic intrusive bodies. **a)** View of southwest face of Copper Mountain from Highway 16, Thornhill. **b)** Kleanza granite, north of Zymoetz River, 05EK01-01, 542077 E, 6039548 N. **c)** Amphibolite and gabbro xenoliths in Shames River intrusion, Dasque Creek, 507286 E, 6025714 N. **d)** Interlayered tonalite and gabbro, Shames River, 506497 E, 6029206 N. **e)** Leucotonalite dikes in Foch tonalite, 484548 E, 5951111 N. **f)** Plagioclase megacrysts, Foch pluton, 484116 E, 5951478 N. **g)** Swarm of mafic xenoliths in Foch tonalite, 483465 E, 5952518 N. **h)** Sheared epidote-rich zone in Foch pluton, 483414 E, 5953006 N.

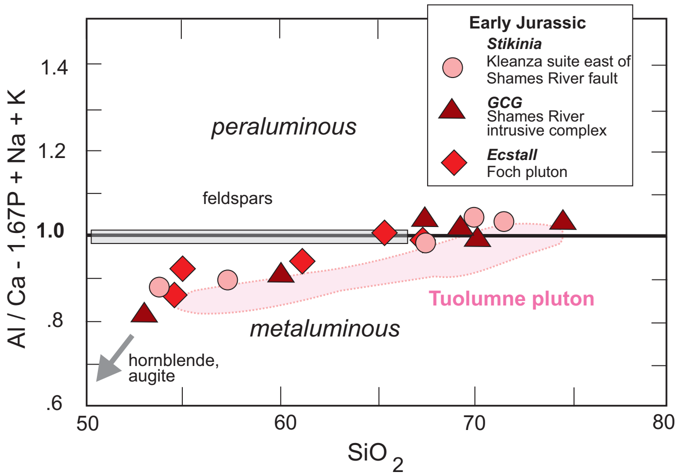

Fig. 11. ASI (aluminum saturation index) vs. SiO_2 for Early Jurassic suite, using modified ASI formula of Frost et al. (2001). Mineral compositions and Tuolumne pluton field from Frost and Frost (2014).

range of phases in the Kleanza and Shames suites. The two lowest silica values from the Foch pluton are from its fine-grained marginal diorite phase.

Primitive mantle-normalized spider plots further illustrate the character of the Early Jurassic suites (Fig. 12). All show the negative Nb, Ti, V, and Sc deflections characteristic of arc-derived igneous rocks, in most accompanied by negative slopes reflecting strong enrichment of LREE. Rocks containing a high modal percentage of plagioclase show positive Eu and Al anomalies that identify them as plagioclase cumulates. Plots of samples from the Foch pluton (Fig. 12a) are consistent, in keeping with the observed homogeneous nature of the body. Most likely, the main Foch pluton formed from a single, differentiating magma phase. In contrast, the Kleanza (Fig. 12b) and Shames (Figs. 12c, d) suites each show significant internal variation in terms of REE slopes, varying enrichment of Al and Zr-Hf, and degree of depletion of Nb and Ti. This suggests that both suites formed through similar processes of cooling of multiple magma batches, each phase with a somewhat different origin and differentiation history. Notably, the spectra of variations in the Kleanza and Shames suites are similar, suggesting common sources and similar differentiation processes.

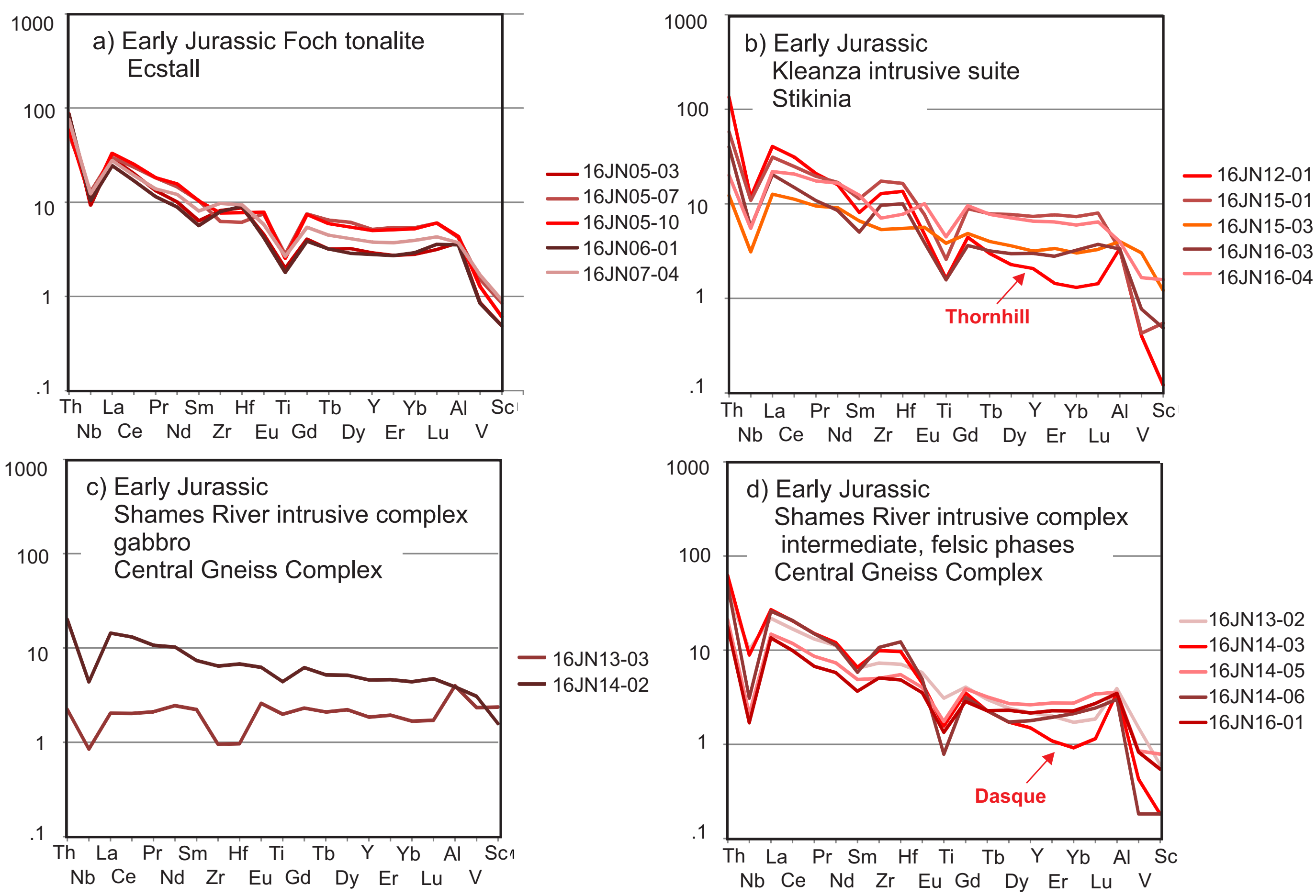

Fig. 12. Spider plots of immobile trace elements for Early Jurassic samples, normalized against primitive mantle values of Sun and McDonough (1989). Choice and order of elements from most to least compatible after Piercey et al. (2006).

Crystal-melt partition coefficients for the rare earth elements display distinct patterns for amphibole relative to garnet (Davidson et al., 2007). For garnet, crystal-melt coefficients correlate negatively with ionic size, decreasing from nearly 10 for Yb to 0.1 for La, whereas hornblende-melt coefficients fall to lower values for LREE and HREE from a MREE peak at Dy (Davidson et al., 2007). Therefore plots of La/Yb and Dy/Yb vs. silica for igneous suites can be used to determine refractory minerals either in residua or as fractionating phases. Most of the Early Jurassic samples from all three suites show increasing La/Yb and decreasing Dy/Yb with increasing silica (Fig. 13). The trends lie close to an amphibole fractionation trend (Smith, 2014). All of these rocks contain hornblende, with modal amounts generally decreasing with higher silica. Thus, in addition to plagioclase fractionation, field observations and trace element behaviour point to hornblende fractionation as an important process.

Two samples stand out as highly anomalous on Figure 13, with very high La/Yb and Dy/Yb ratios, and similar overall trace element profiles on Figure 12. They include: a) the Thornhill granodiorite phase of the Kleanza pluton (16JN12-01); and b) a Shames River suite mafic-poor, well-foliated granodiorite (16JN14-03). Their extreme LREE and MREE enrichment is consistent with abundant garnet in a residual phase. Strong depletion in compatible elements V and Sc and high values of incompatible Th identify these rocks as more evolved than the rest of the suite. Their chemistry is consistent with a complex origin. The strong LREE enrichment and depletion of compatible elements suggests a parent with a much smaller degree of partial melting than the rest of the Early Jurassic suite. These rocks could have evolved through multiple crystallization-remelting cycles at the base of a thick crust or in the sub-arc mantle.

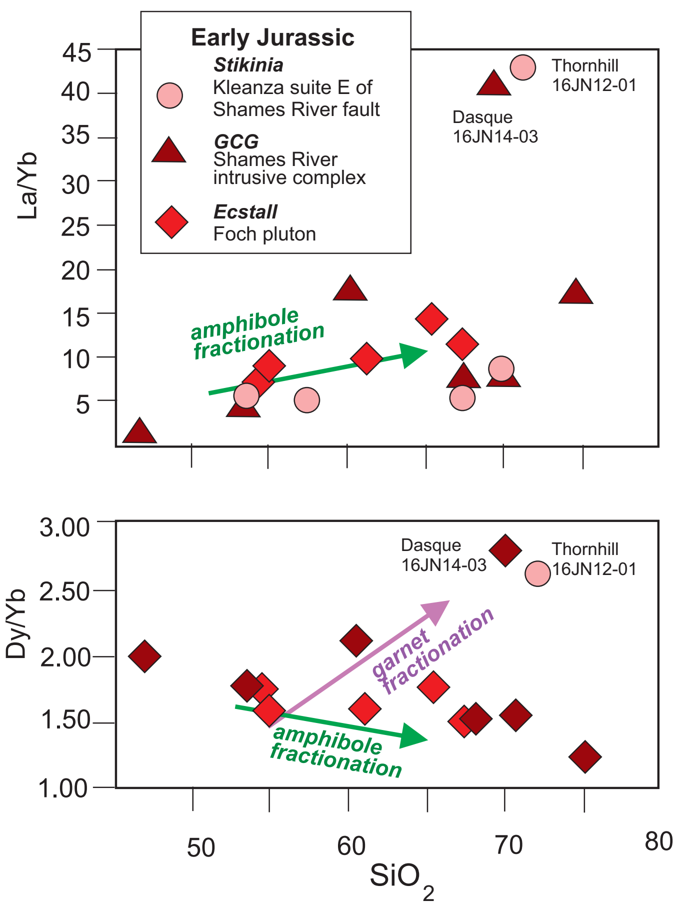

Fig. 13. La/Yb and Dy/Yb vs. for Early Jurassic suite. Amphibole fractionation arrow from Smith (2014). Garnet fractionation arrow from Davidson et al. (2007).

2.2.2.5. Telkwa rhyolite with Precambrian inheritance

A sample of red, coherent dacite from the Telkwa Formation, 05TB26-10, yielded three discordant zircon fractions (Fig. 14). Two-point discordia, based on the youngest fraction and each of the two oldest fractions have Early Jurassic lower intercepts and Paleoproterozoic upper intercepts. The lower intercepts, 204.0 ±5.4 Ma and 205.5 ±4.4 Ma, are close to the actual age of the dacite, because it lies stratigraphically above a 204.29 ±0.45 Ma rhyolite and below a 194.35 ±0.32 Ma rhyolite (Barresi et al., 2015). The upper intercepts at ca. 1605 and 1779 Ma reflect Precambrian cores in igneous zircons.

2.3. Discussion

New data presented above test potential correlation and continuity of late Paleozoic and Early Jurassic units from Stikinia near Terrace into the Coast Mountains orogen to the west. Ages of late Paleozoic volcanic and intrusive units near Terrace (325-323 Ma) agree with a previously reported, less precise age of 331-317 Ma (Heah, 1991). These ages are somewhat younger than the single age available from the Ecstall belt (336.8 ±17.7 Ma), but overlap within error. Late Paleozoic igneous suites in both Stikinia and the Ecstall belt are bimodal. Mafic rocks are of non-arc origin, E-MORB in Ecstall

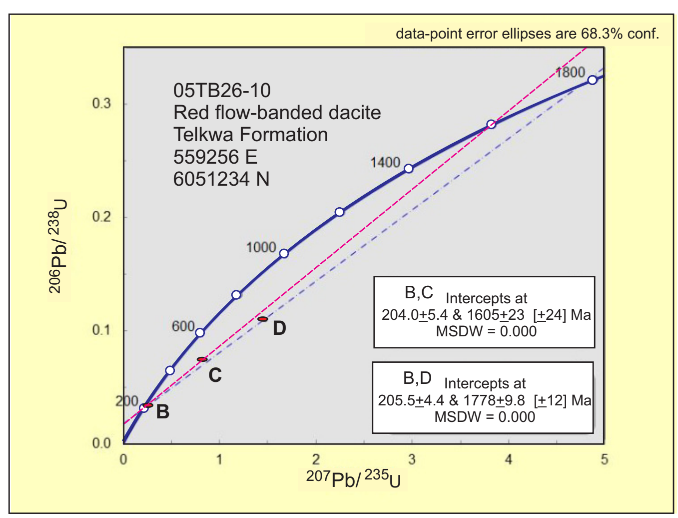

Fig. 14. Concordia plot for zircons from Telkwa Formation rhyolite, 05TB26-10. Proterozoic upper intercepts are from cores in two zircon fractions.

and BABB in Stikinia, whereas felsic rocks are calc-alkaline. Coexisting felsic arc and mafic non-arc suites are common in late Paleozoic assemblages of the Yukon-Tanana terrane, where rocks of non-arc affinity have been attributed to back-arc extension (Piercey et al., 2006). The similar age and character of these suites suggests late Paleozoic commonalities between Stikinia and the Ecstall belt. However, because late Paleozoic igneous rocks are throughout northern Stikinia (Gunning et al., 2006), they do not constitute a precise link.

Early Jurassic intrusions such as the Kleanza suite (western Stikinia), the Shames River orthogneiss (Coast Mountains orogen) and the Foch pluton (Ecstall belt) form a continuum of major element compositions that define them as a calc-alkalic, mainly magnesian, metaluminous magmatic suite that evolved to slightly ferroan and peraluminous at highest SiO_2 values. For most of the suite, increase of La/Yb at higher SiO_2 with corresponding decrease of Dy/Yb is consistent with hornblende fractionation. Positive Al and Eu peaks in spider plots indicate plagioclase fractionation. Minor element profiles for the Kleanza and Shames River suites show similar degrees of internal variability, suggesting involvement of multiple melts. Notably, one sample from each suite shows extreme LREE enrichment, characteristic of strong influence by residual garnet.

Based on their petrologic and geochemical similarities, it is likely that the Shames River intrusive complex represents deeper levels of the Kleanza intrusive suite (Fig. 3). Restoring normal displacement on the Shames River fault and the Shames River detachment zone places the Terrace region structurally above the Central Gneiss Complex in the Late Cretaceous. This configuration was partly created by Cretaceous crustal shortening and west-vergent ductile deformation in the Coast Mountains orogen. However, the parallels between the Kleanza and Shames River intrusive suites suggest that an earlier link existed, at least as deep as the base of the Shames River complex.

The Foch pluton is coeval with the Kleanza intrusive suite and forms part of a geochemical continuum with it. The position of the Foch and Johnson plutons on a western continuation of the east-northeasterly trend of the Kleanza intrusive suite (Figs. 1, 2) is consistent with emplacement of all these bodies into a set of magma chambers controlled by a system of structurally controlled lower crustal conduits. The east-northeast trend of the Early Jurassic intrusive suite coincides with the Skeena arch (Fig. 1), a long-lived crustal discontinuity oriented at a high angle to Stikinia. Association of the Foch and Johnson plutons with the Kleanza suite suggests that the same basement discontinuity extends underneath the Ecstall belt. The deep structures that accommodated Early Jurassic intrusions of the Kleanza and related suites may have played a role equivalent to strands of the Pitman fault array farther north, notably the Boundary fault, which hosts the Red stock and Red Chris porphyry deposit. Long-lived, recurrent uplift of the Stikine and Skeena arches was triggered by differential movement across these deep crustal discontinuities. These discontinuities also likely provided conduits at times of high magmatic flux, most notably during development of the Hazelton arc and its associated intrusions in the latest Triassic-Early Jurassic.

3. Mt. Clashmore supracrustal rocks

Building on mapping and geochronologic studies by Evenchick and McNicoll (2002), fieldwork near Mt. Clashmore in 2016 focused on remapping Lower to Middle Jurassic supracrustal rocks (Fig. 15) and resampling conglomeratic rocks for detrital zircon geochronology. Below I consider the possible relationship between these supracrustal rocks and deposits in the main Eskay rift; geochronologic results are pending.

Evenchick and McNicoll (2002) mapped across the southernmost exposures of the Eskay rift, where a predominantly basalt succession hosts Anyox, a Cu-rich volcanogenic deposit. Supracrustal rocks in the rift and near Mount Clashmore to the west (Fig. 15) both yielded zircons as young as late Early to Middle Jurassic, which they recognized as coeval with host rocks of the Eskay Creek volcanogenic orebody (186-173 Ma; Evenchick and McNicoll, 2002). Although they considered the Jurassic successions part of the Hazelton Group, they assigned those west of Anyox (central and western belts) to the Mt. Clashmore complex, a tectonically-defined unit that also contains fault-bounded panels of deformed Late Devonian and late Early Jurassic intrusive rocks (Fig. 15).

Of 11 zircons from a conglomerate sample analyzed by Evenchick and McNicoll (2002) from Mt. Clashmore (EP-96-319-14, Fig. 15), seven yielded Precambrian-Cambrian ages (SHRIMP; 1058, 1023, 987, 918, 612, 560, and 517 Ma), which have not been found to the north, in the Yukon-Tanana terrane.

Stratified units on Mt. Clashmore include basalt pillow breccia (Fig. 16a) and mafic tuff, siliciclastic strata, and minor rhyolite and rhyolite tuff, cut by coeval basalt, diabase, and gabbro dikes (Fig. 15). They occur in two panels, in steep fault contact with intervening sheared late Early Jurassic (ca. 177 Ma) granodiorite. Igneous rocks are bimodal, with a basalt:rhyolite ratio of >100:1. The only rhyolite body of mappable size is on the eastern margin of the assemblage, next to the Main Break fault (Fig. 15). At the margins of this body, large, angular rhyolite clasts float in a black argillite matrix (Fig. 16b). Fine-grained sedimentary layers consist of thinly bedded siliceous argillite and chert with pale felsic tuff laminae (Fig. 16c). East of the Mt. Clashmore summit, the polymictic conglomerate sampled by Evenchick and McNicoll (2002) forms a single, continuous layer stratigraphically above coarse, poorly layered monomictic breccia derived from the granodiorite (Fig. 16d). The conglomerate contains white felsic volcanic clasts, dark grey mudstone wisps and intraclasts, and rare grey chert and limestone clasts (Figs. 16e, f). Except for the chert and limestone, the clasts are probably intraformational. Farther west, on the southern slope of Mt. Clashmore, polymictic breccia/conglomerate contains clasts of basalt and fine-grained gabbro in a dark argillaceous matrix.

Evenchick and McNicoll (2002) concluded that the Jurassic

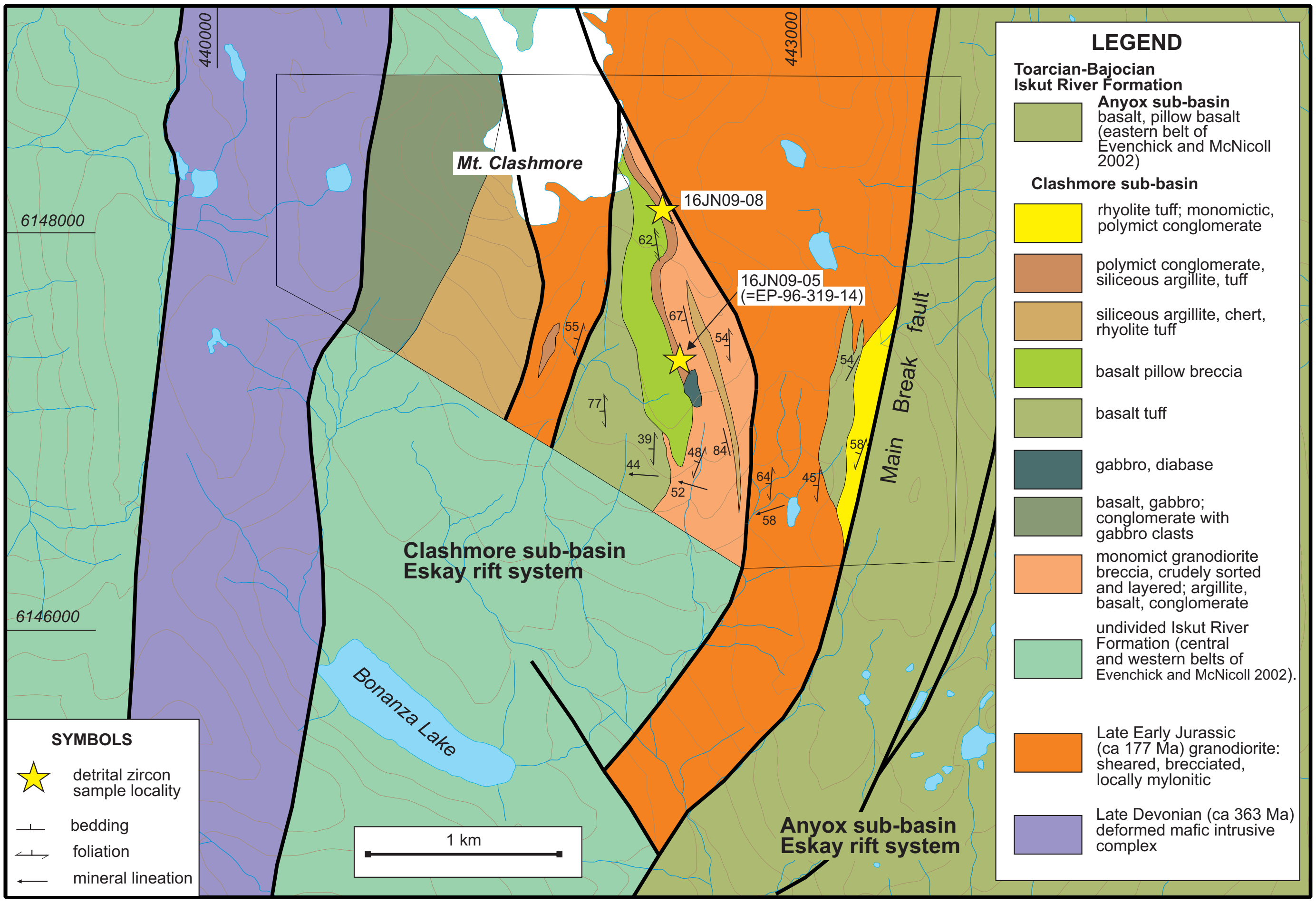

Fig. 15. Geology of the Mt. Clashmore area. Regional geology from Evenchick and McNicoll (2001) and Alldrick (2003). See Figure 1 for context.

volcanosedimentary strata at Mt. Clashmore accumulated in graben adjacent to active normal faults, and that erosional stripping of intervening horsts provided clasts to conglomeratic units. The Grenville to Neoproterozoic to Cambrian detrital zircons were likely derived from horsts or rift-flank uplifts within or adjacent to the Eskay rift in the late Early to Middle Jurassic. The argillite-matrix rhyolite breccia, like rhyolite peperites in the northern part of the rift (Alldrick et al., 2004), is interpreted as the collapsed carapace of a subaqueous dome or cryptodome.

The association of late Early to Middle Jurassic bimodal volcanic and subvolcanic rocks with intervals of thinly bedded, fine-grained sedimentary strata and thickly bedded conglomeratic units favours correlation with the Iskut River Formation, a sequence of basalt, rhyolite, fine-grained siliceous argillite with pale tuff laminae ('pyjama beds') and siliciclastic deposits that form the fill of the Eskay rift in Iskut area, west-central Stikinia (Gagnon et al., 2012). The minimum detrital ages reported by Evenchick and McNicoll (2002) are coeval with the Iskut River Formation. Supracrustal rocks near Mt. Clashmore are separated from the mainly basaltic sequence that hosts the Anyox deposit only a few km to the east by the Main Break fault (Alldrick, 2003). The two sequences were probably deposited in separate sub-basins of the Eskay rift system. I propose that all of the Jurassic supracrustal rocks in the Mt. Clashmore area be assigned to the Iskut River Formation, and that the term 'Clashmore complex' be abandoned.

Detrital zircon populations comparable to the Grenvillian or Neoproterozoic to Cambrian suite at Mt. Clashmore have not been reported from the Yukon-Tanana terrane, where Late Devonian and younger arc-related igneous assemblages are superimposed on continent margin strata with Archean to Paleoproterozoic zircon populations probably sourced from northwestern Laurentia (Nelson et al., 2006a). With a non-northwestern Laurentian zircon population, immediately adjacent Precambrian source rocks interpreted to have fed sediment directly into the southern Eskay rift contrast strongly with the Yukon-Tanana terrane that underpins the far northern part of Stikinia. Analysis of samples collected from this conglomerate in 2016 will provide a statistically valid data set to evaluate local basement sources.

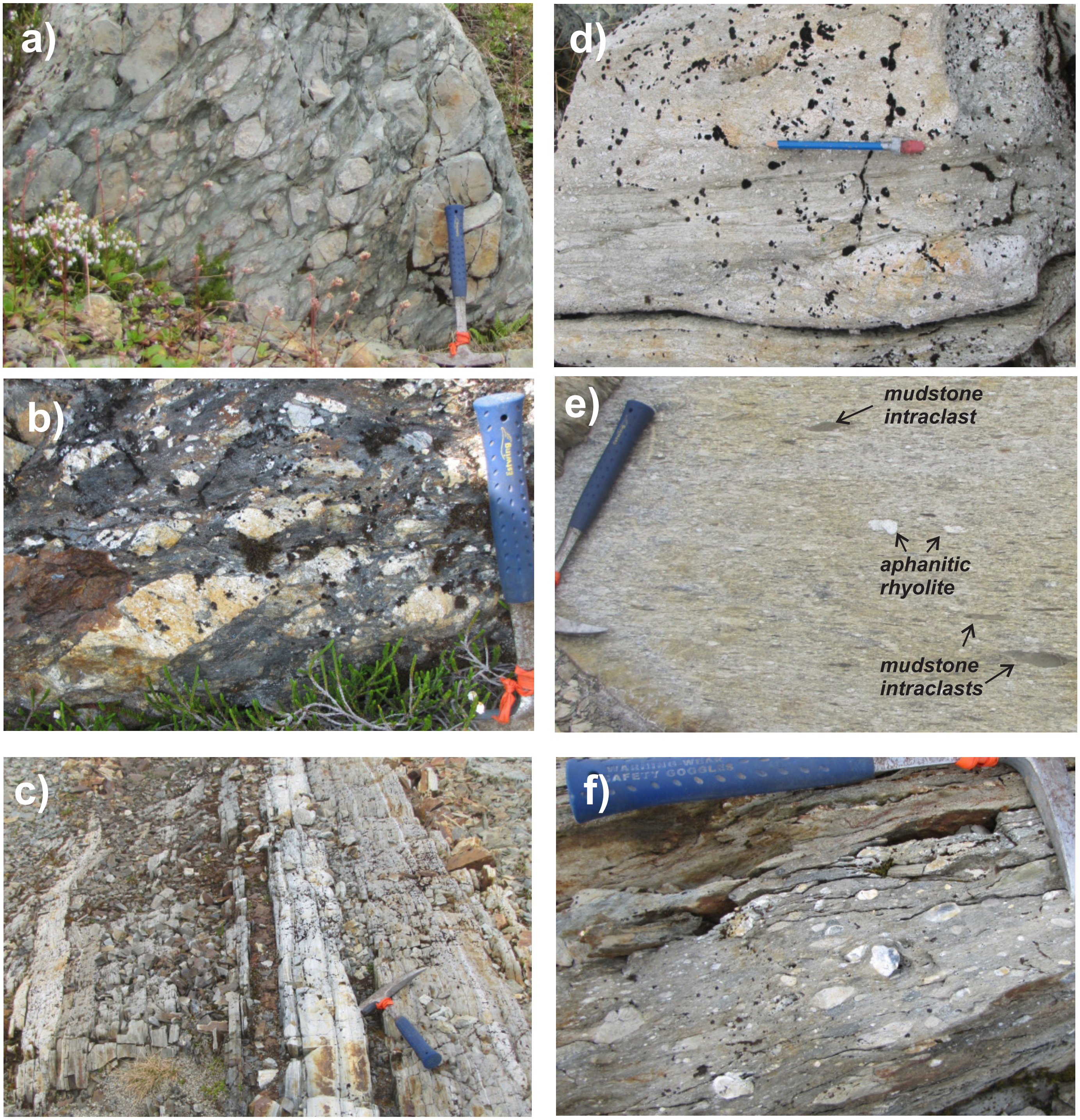

Fig. 16. Photos of Iskut River Formation units on Mt. Clashmore. **a)** Pillow breccia, 442435 E, 6147087 N. **b)** Rhyolite fragments in black argillite matrix, 443230 E, 6147529 N. **c)** Thin-bedded to laminated siliceous argillite and felsic tuff, 442408 E, 6147132 N. **d)** Sheared monomictic granodiorite breccia, 442478 E, 6146918 N. **e)** Heterolithic conglomerate at detrital zircon sample site 16JN09-06, 442380 E, 6147465 N. **f)** Heterolithic conglomerate with light grey chert clasts at detrital zircon sample site 16JN09-08, 442283 E, 6148076 N.

4. Conclusions

Early Jurassic plutons east of and within the Coast Mountains orogen between Terrace and Prince Rupert show strong geochemical similarities and were probably parts of a single magmatic system emplaced along a structurally controlled corridor related to the Skeena arch. Furthermore, similarities in age and chemistry of Mississippian igneous rocks of the Ecstall belt to those of Stikinia suggest that the Ecstall belt formed part of the pre-mid Paleozoic basement of the terrane. The structural corridor was certainly of pre-Jurassic origin, and may have existed before the Devonian, the age of the oldest known rocks of the Ecstall belt.

Late Early to Middle Jurassic supracrustal rocks near Mt. Clashmore, west of Anyox, represent a different facies compared to the immediate host rocks of the Anyox deposit and likely record separate sub-basin development in the southern Eskay rift. The succession at Mt. Clashmore has not been previously considered to have potential for volcanogenic occurrences. Correlation with the Iskut River Formation in the main Eskay rift and small rhyolite centres within it favour further exploration.

The Middle Devonian arc assemblage of the Ecstall belt and the cryptic Grenvillian-Cambrian source to the Mt. Clashmore conglomerate each represent distinct components within the pre-late Paleozoic basement of Stikinia. They differ from each other and from the Yukon-Tanana terrane, which underlies the Stikine assemblage at the far northern end of the terrane. The extreme contrasts between them, compared to the more homogeneous and continuous younger units, support the idea that these disparate crustal fragments amalgamated in a cryptic mid-Paleozoic collision before deposition of the Stikine assemblage and intrusion of cogenetic plutons such as More Creek and Forrest Kerr. The N-S and E-W fault arrays cut across all basement components. They probably initiated after accretion and before or during the first onset of Stikine assemblage magmatic activity.

Detrital zircon studies now in progress for samples from Mt. Clashmore are anticipated to shed additional light on the nature of Paleozoic and Precambrian basement units of west-central Stikinia.

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