'Windy-McKinley' terrane, western Yukon: new data bearing on its composition, age, correlation and paleotectonic settings

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ABSTRACT

New geochronological and geochemical data from the 'Windy-McKinley'* terrane provide insight into the age, correlation and paleotectonic settings of the various subdivisions of the terrane. U-Pb zircon age determinations for felsic meta-volcanic rocks of the White River formation and gabbro intrusions are Late Devonian and late Middle Triassic respectively. These new age determinations substantiate the proposed correlation of these components of 'Windy-McKinley' terrane with the succession on strike to the northwest which hosts the volcanogenic massive sulphide deposits in the Delta District, Alaska. Trace-element geochemical data from Triassic gabbro intrusions into the Mirror Creek and White River formations, and diabase and gabbro of the Harzburgite Peak-Eikland Mountain ophiolite suggest that magmatism in both subdivisions occurred in supra-subduction zone settings. However, the age of the ophiolite is not known, therefore mafic magmatism may not be coeval across the terrane and may have formed above different subduction zones at different times.

*Quotes are used to indicate that the assignment to Windy and McKinley terranes is obsolete, but a new name has not yet been assigned.

RÉSUMÉ

Les nouvelles données géochronologiques et géochimiques obtenues sur le terrane de Windy-McKinley donnent une idée de l'âge, de la corrélation et du cadre paléotectonique des diverses subdivisions du terrane. D'après les datations (zircons) à l'U/Pb par ablation au laser ICP-MS, les roches métavolcaniques felsiques de la Formation de White River et les intrusions métagabbroïques datent respectivement du Dévonien tardif et du Trias moyen tardif. Ces nouvelles datations justifient la corrélation proposée de ces composantes du terrane Windy-McKinley avec la succession suivant le décrochement vers le nord ouest, qui contient des dépôts sulfurés massifs volcanogènes dans le district de Delta (Alaska). Les données géochimiques sur les éléments traces des intrusions de gabbro du Trias dans les Formations de Mirror Creek et de White River et sur les éléments traces du diabase et du gabbro du complexe d'ophiolite du pic Harzburgite et de la montagne Eikland suggèrent que dans les deux sous-divisions, le magmatisme est survenu dans un contexte de supra-zone de subduction. Toutefois, l'âge de l'ophiolite est inconnu. Par conséquent, le magmatisme mafique pourrait ne pas être du même âge dans l'ensemble du terrane et pourrait s'être produit au dessus de zones de subduction différentes et à des moments différents.

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INTRODUCTION

The 'Windy-McKinley' terrane of western Yukon is a poorly exposed assemblage of schists and ophiolitic rocks that are along strike from, and have been correlated with, rocks of the Windy and McKinley terranes of the Alaska Range (Wheeler and McFeeley, 1991; Monger *et al.*, 1991; Silberling *et al.*, 1992; Gordey and Makepeace, 2001; Fig. 1). Based on reconnaissance mapping in the early 1970s (Tempelman-Kluit, 1974), the correlation with the Windy and McKinley terranes of the Alaska Range has since been placed in doubt owing to several recent studies of the 'Windy-McKinley' terrane of Yukon which have documented the lithological character of the terrane in greater detail and provided preliminary insights into its origin and evolution (Canil and Johnston, 2003; Mortensen and Israel, 2006; Murphy, 2007; Murphy *et al.*, 2007, 2008). The terrane is now known to be composed of two lithostratigraphic assemblages, an imbricated ophiolitic assemblage (Canil and Johnston, 2003) known as the Harzburgite Peak – Eikland Mountain ophiolite, and an assemblage of variably deformed schists of meta-sedimentary and meta-igneous protoliths (White River and Mirror Creek formations, Murphy *et al.*, 2007, 2008). The schist assemblage has been extensively intruded by variably deformed gabbro of late Middle Triassic age (Mortensen and Israel, 2006). Murphy *et al.* (2008) proposed that the schist and gabbro assemblage correlates with rocks of the Jarvis and Hayes Glacier belts of Alaska's Delta volcanogenic massive sulphide (VMS) district (Dashevsky *et al.*, 2003; Dusel-Bacon *et al.*, 2006 and references therein), citing the association of Triassic gabbro and felsic metavolcanic rocks, an association rarely found in the Cordillera. The age of the Harzburgite Peak – Eikland Mountain ophiolite has not been determined, hindering attempts at correlation; Murphy (2007) proposed correlation with the Chulitna terrane, a mid-Paleozoic supra-subduction zone ophiolite on the opposite side of the Denali fault (Clautice *et al.*, 2001 and references therein).

In this paper, we present new data on the composition, age, correlation and paleo-tectonic settings of the two lithostratigraphic assemblages of 'Windy-McKinley' terrane. We present preliminary U-Pb age determinations on igneous zircons from felsic meta-volcanic rocks from the White River formation and Triassic gabbro bodies that have implications for the proposed correlation of these rocks with the rocks of the Delta VMS District. Secondly, we present preliminary U-Pb age determinations on detrital zircons from meta-clastic rocks of 'Windy-McKinley' and Yukon-Tanana terranes that bear on potential correlations and terrane affinities. Finally, we present preliminary whole rock geochemical data from mafic rocks of the undated Harzburgite Peak – Eikland Mountain ophiolite and Triassic gabbro that establish them as products of supra-subduction zone magmatism. This conclusion affirms the proposed correlation of the ophiolitic rocks with a supra-subduction zone ophiolite on the

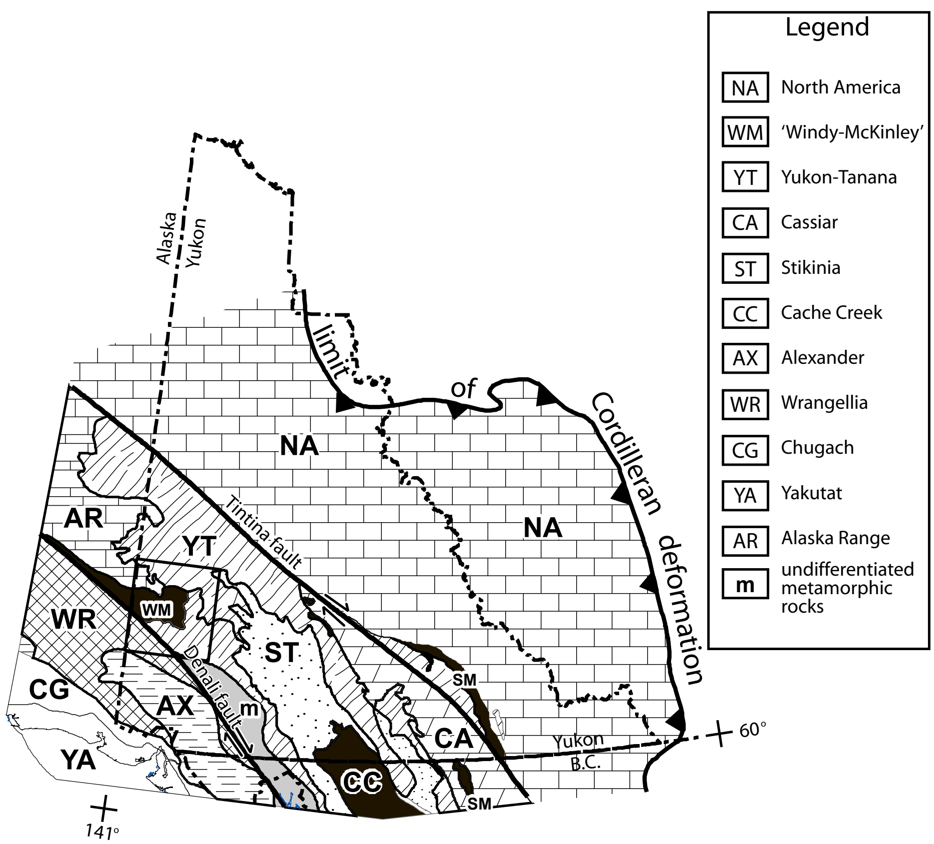

Figure 1. *Terrane map illustrating the distribution of 'Windy-McKinley' terrane in western Yukon and eastern Alaska (modified after Colpron et al., 2006). Box indicates area of focus of this paper.*

opposite side of the Denali fault, part of the Chulitna terrane of Alaska.

'WINDY-MCKINLEY' TERRANE, STEVENSON RIDGE AND KLUANE LAKE AREAS

The two lithostratigraphic assemblages of 'Windy-McKinley' terrane have been documented throughout western Stevenson Ridge area (115JK; Murphy, 2007; Murphy *et al.*, 2007, 2008) and have been traced southwardly into northern Kluane Lake area (115FG; Fig. 2). The meta-sedimentary and meta-volcanic schist and gabbro assemblages occur to the west and structurally beneath the Harzburgite Peak – Eikland Mountain ophiolite, and both overlie Yukon-Tanana terrane along a thrust fault.

Murphy *et al.* (2008) divided the schist assemblage into two formations, the felsic (and lesser mafic) meta-volcanic and meta-sedimentary White River formation and the variably carbonaceous and calcareous meta-clastic Mirror Creek formation. Both of these rock units are spatially associated, but in unknown contact relationships, with a quartz-rich meta-clastic unit, herein called the Scottie Creek formation. Murphy *et al.* (2007, 2008) correlated the Scottie Creek formation with the Yukon-Tanana terrane; however, spatial association of the Scottie Creek formation with bodies of gabbro, and new detrital zircon data presented herein support the interpretation that this unit is in stratigraphic succession with the White River and Mirror Creek formations.

All of the schist formations are intruded by, and locally deformed together with, variably foliated gabbro. Gabbro intruding the Mirror Creek formation was previously reported to be late Middle Triassic in age (*ca.* 228 Ma, Mortensen and Israel, 2006). This paper presents new U-Pb geochronological results that document the ages of gabbro bodies which intrude, or are interfoliated with, rocks of the Mirror Creek, White River and Scottie Creek formations.

The Harzburgite Peak – Eikland Mountain ophiolite extends from northeast to southwest across Stevenson Ridge map area and has been traced southeasterly into Kluane Lake map area where it occurs in a tight synformal keel (Fig. 2). The ophiolite is imbricated (Canil and Johnston, 2003; Murphy *et al.*, 2008) and upper mantle harzburgite, lower crustal gabbro and dunite, and mid-crustal diabase micro-gabbro are generally the best preserved and exposed parts of the ophiolite. Supracrustal rocks, mainly multi-coloured chert and argillite, occur rarely (Murphy, 2007; Wellesley Lake formation of Murphy *et al.*, 2007, 2008). Preliminary geochemical analyses of diabase from the ophiolite revealed compositions transitional between normal and enriched mid-ocean ridge basalt (Murphy *et al.*, 2008). Below, we present geochemical data from a more comprehensive suite of samples that supports a supra-subduction zone setting for the ophiolite.

U-PB GEOCHRONOLOGICAL STUDIES

Five preliminary U-Pb igneous and six preliminary detrital zircon age determinations are reported here. One sample of felsic meta-volcanic rock of the White River formation was collected from outcrops southeast of the confluence of the White and Donjek rivers. Four samples of foliated gabbro were collected. Of these four samples, one sample is from an isolated body of foliated gabbro within a Cretaceous pluton, but on strike from similar bodies of gabbro spatially associated with the Scottie Creek formation. Another sample is from a large body of gabbro interfoliated with a band of felsic metavolcanic rocks from which the dating sample of the White River formation was collected. The remaining two samples are from bodies of weakly deformed gabbro which intrude the Mirror Creek formation along the Alaska Highway. Finally, of the six detrital samples, three are meta-sandstone from the Mirror Creek formation, two are from the Scottie Creek formation, and one is from the oldest (structurally deepest) quartz-rich meta-clastic unit of Yukon-Tanana terrane. Zircon and baddeleyite recovered from igneous and detrital samples were analyzed using both conventional ID-TIMS and laser ablation LA-ICP-MS U-Pb methods at the Pacific Centre for Isotopic and Geochemical Research. Analytical methods are as described in Mortensen (this volume). As these data are preliminary, we present only plots of the data, in the following formats: concordia diagrams, weighted mean plots, or probability plots; data tables will be presented when the age determinations are finalized.

AGE OF THE WHITE RIVER FORMATION

Of twenty zircons extracted from a sample of quartz- and feldspar-porphyritic, crystal-lithic meta-tuff of the White River formation (Fig. 3a), nine zircons were less than 5% discordant. A weighted average of their $^{206}Pb/^{238}U$ ages is 363.0 ± 3.1 Ma and is interpreted as the crystallization age for this rock (Fig. 3b).

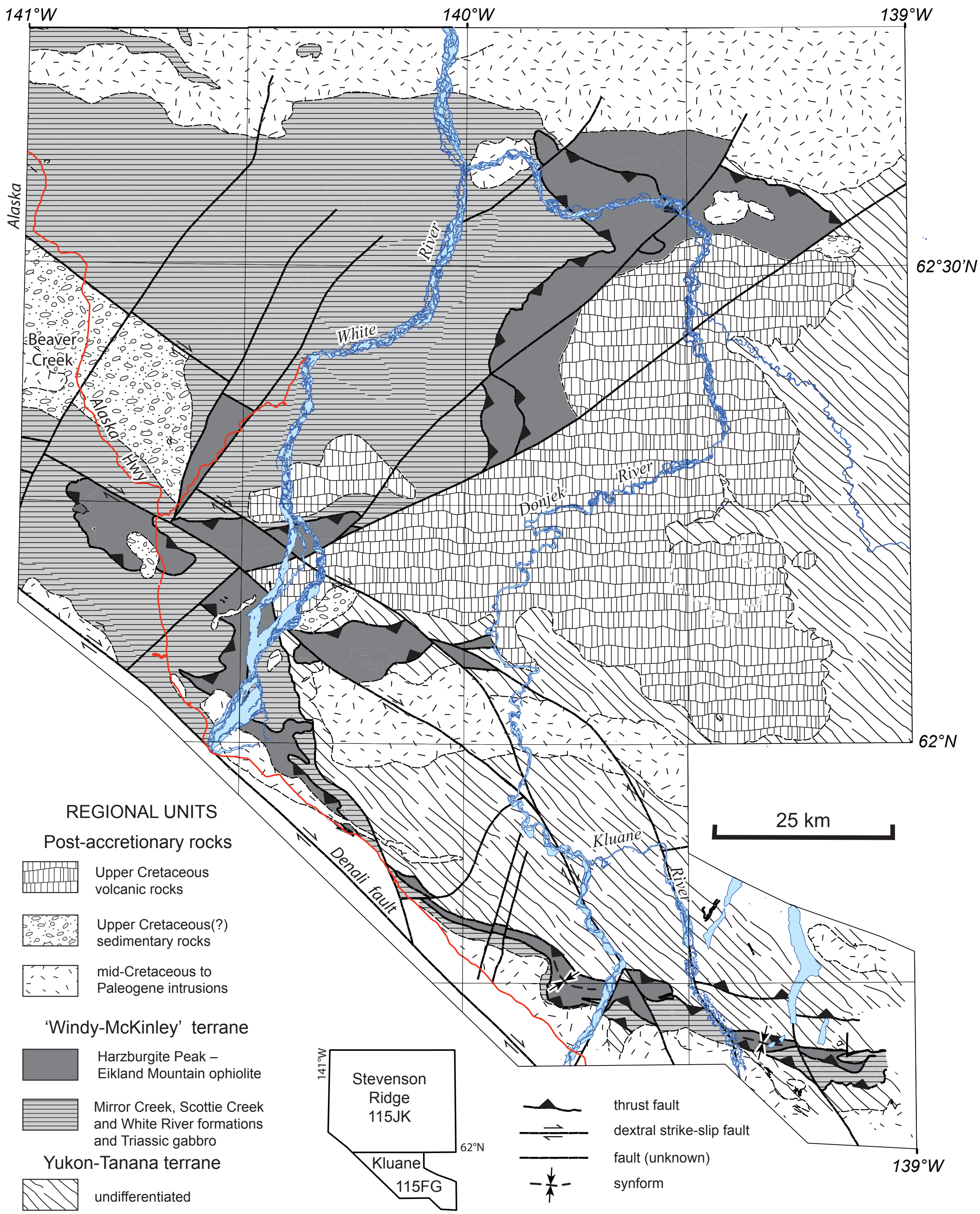

Figure 2. *Simplified geology of western Stevenson Ridge and northern Kluane Lake map areas, modified from Murphy et al., (2007).*

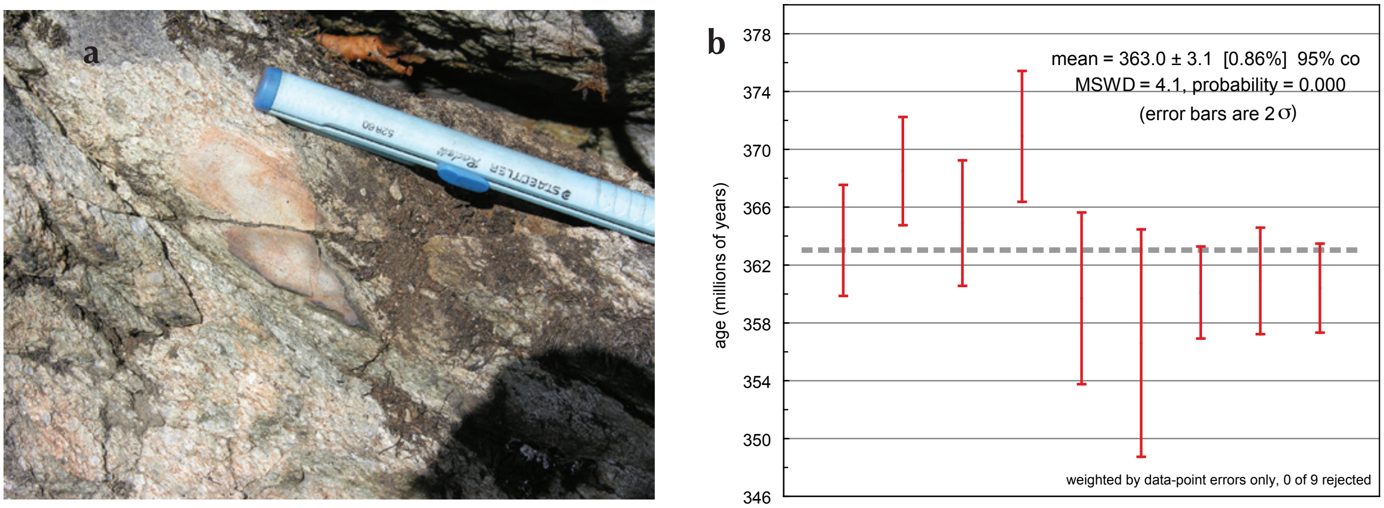

Figure 3. (a) *Foliated quartz- and feldspar-porphyritic crystal-lithic tuff of White River formation; sample for dating collected at this outcrop.* ***(b)*** *Weighted mean $^{236}U/^{208}Pb$ age of sample collected from outcrop shown in (a).*

AGE OF GABBRO

Small amounts of zircon and/or baddeleyite were recovered from four samples of gabbro. Both baddeleyite and air-abraded zircons were analyzed from samples 01M-06 and 01M-08 (which are in close proximity to each other). For sample 01M-06, two fractions of air-abraded zircon give overlapping concordant analyses resulting in a $^{206}Pb/^{238}U$ age of 228.2 ± 0.8 Ma (Fig. 4a), which is inferred to be the crystallization age of the gabbro. A third fraction of zircon and a single fraction of unabraded baddeleyite yield slightly younger $^{206}Pb/^{238}U$ ages, reflecting the effects of minor post-crystallization Pb-loss. Three fractions of abraded zircon from sample 01M-08 (Fig. 4b) give a range of relatively young $^{206}Pb/^{238}U$ ages; however, a single fraction of unabraded baddeleyite gives a $^{206}Pb/^{238}U$ age of 227.1 ± 0.6 Ma, which is in excellent agreement with the zircon age from sample 01M-06. The younger ages from the three zircon analyses is interpreted to result from post-crystallization Pb-loss. Sample 04M-41 yielded a very small amount of baddeleyite, which was analyzed in two fractions. Both fractions yield concordant analyses (Fig. 4c). The best estimate for the crystallization age of 04M-41 is given by the older, more precise $^{206}Pb/^{238}U$ age, at 227.2 ± 0.6 Ma. A fourth sample of gabbro (sample 07DM-167) yielded abundant zircon, and was analyzed using LA-ICP-MS methods. The weighted average of the $^{206}Pb/^{238}U$ ages from 20 individual analyses is 230.9 ± 2.7 Ma (Fig. 4d), which is interpreted as the crystallization age of the sample.

These preliminary ages for four bodies of variably foliated gabbro range from *ca.* 227 to 231 Ma, indicating that late Middle Triassic gabbro intruded all the formations of the schist assemblage of the 'Windy-McKinley' terrane, a conclusion previously inferred on the basis of their similar geochemical compositions (Murphy *et al.*, 2008).

DETRITAL ZIRCON ANALYSES

Our analyses show that each stratigraphic unit has a distinctive detrital zircon signature. Samples from the Mirror Creek and Scottie Creek formations are similar in the older portions of their detrital zircon spectra, but differ in the younger; both differ from the Yukon-Tanana terrane sample.

Yukon-Tanana terrane grit

The sample of Yukon-Tanana terrane grit (Fig. 5) yielded a relatively simple bimodal pattern with prominent age peaks at 1.7 to 2.0 Ga and 2.5 to 2.8 Ga. Single zircon ages at *ca.* 2.1 and 2.9 Ga just outside these intervals may indicate a greater peak width, however a bimodal pattern would still be apparent.

Scottie Creek formation grit

The samples from the Scottie Creek formation (Fig. 5) are more complex. Both samples have a broad multimodal peak between 1.0 and 1.5 Ga, a prominent 1.7 to 2.0 Ga peak, and a broad multimodal peak between 2.6 and 2.8 Ga. One sample has a single zircon at *ca.* 340 Ma and multi-grain peaks at *ca.* 1.6, 2.35 and 2.45 Ga; these latter intervals are represented by single grains in the other sample. Sample 06DM178 also has single grains at 2.80 to 2.85 Ga and 2.85 to 2.90 Ga.

Mirror Creek formation meta-sandstone

The detrital age spectra for samples of the Mirror Creek formation (Fig. 5) are similar to those of the Scottie Creek formation for ages older than 1.0 Ga, but also include Neoproterozoic and Lower Paleozoic zircons. A prominent multi-grain peak at *ca.* 450 Ma is common to all Mirror Creek samples, a two-grain peak at *ca.* 550 Ma occurs in two of the samples, and one sample has single grain peaks at *ca.* 650 and 700 Ma.

WHOLE-ROCK GEOCHEMICAL DATA

Three sets of samples were systematically collected during the 2006 to 2008 field seasons for whole-rock geochemical analysis. One set of samples targeted diabase and micro-gabbro from the upper to mid-crustal part of the Harzburgite Peak – Eikland Mountain ophiolite.

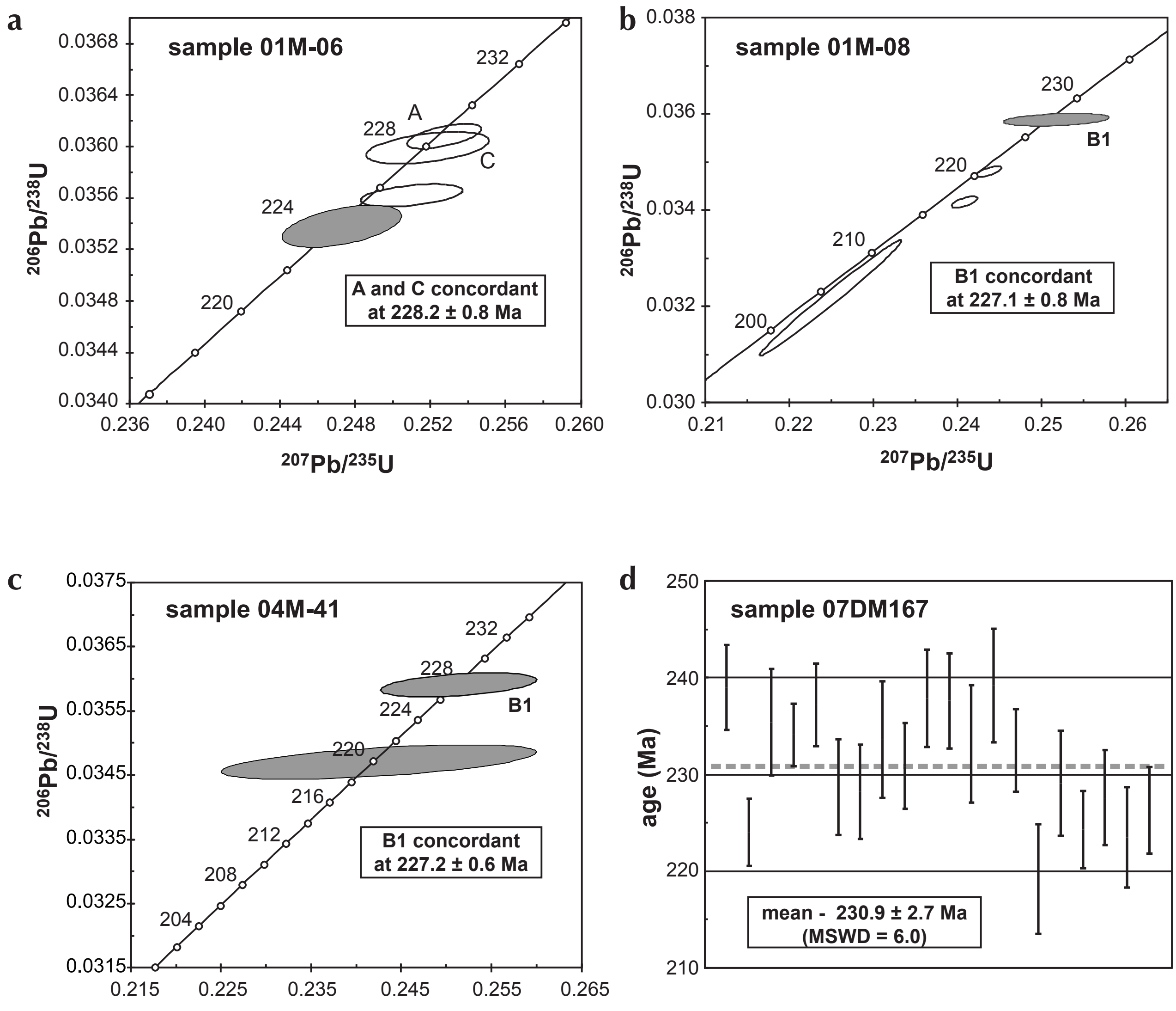

Figure 4. *U-Pb analyses for zircon and baddeleyite from gabbro of the schist-gabbro subdivision of 'Windy–McKinley' terrane. Figures 4a-c are plots of ID-TIMS analyses. Error ellipses (zircon = open elipses; baddeleyite = grey elipses) are at the 2-σ level. Figure 4d is a plot of analyses from sample 07DM-167, which was determined using laser ablation ICP-MS methods. Error bars on individual analyses are at the 2-σ level. MSWD refers to the "mean square of the weighted deviates".*

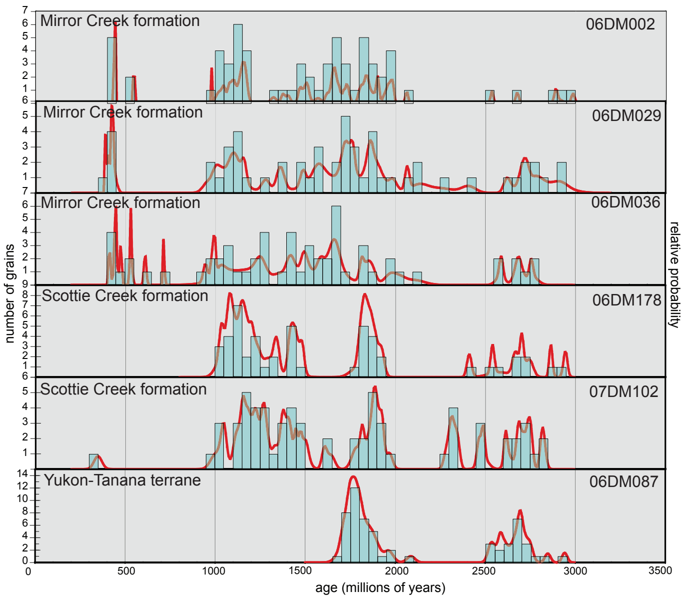

Figure 5. *Probability distribution plots showing detrital zircon age distributions for two formations of ‘Windy-McKinley’ terrane (Mirror Creek and Scottie Creek formations) and Yukon-Tanana terrane. See text for discussion.*

A second set of samples of foliated greenstone of unknown protolith, yet spatially associated with chert and argillite, was collected from the supracrustal part of the ophiolite. The third set of samples is from bodies of Triassic gabbro intruding the schist assemblage. Samples were selected and prepared to be free of weathered surfaces, veins and alteration before being sent to Activation Laboratories of Ancaster, Ontario for research-grade analyses. In 2007, major element analyses were done by XRF and trace elements by ICP fusion mass spectrometry. In 2008, all elements were analyzed by ICP fusion mass spectrometry. Owing to the relative resistance of certain trace elements to changes in composition during epigenetic processes such as sea-floor metamorphism, orogenic metamorphism or metasomatism, most geochemical studies of deformed and/or metamorphosed igneous rocks in orogenic belts utilize the concentrations of trace-element in their analyses (e.g., Shervais and Metcalf, 2003; Piercey *et al.*, 2006), a practice which was followed during our analyses.

HARZBURGITE PEAK – EIKLAND MOUNTAIN OPHIOLITE

Seventeen samples from the ophiolite were analyzed. Eleven of these are from massive to weakly plagioclase-porphyritic diabase or micro-gabbro occurring above coarse-grained gabbro in the ophiolite succession. The remaining six of these samples are from bodies of variably foliated greenstone spatially associated with the chert and argillite in the supracrustal part of the ophiolite, but of unknown protolith. The ophiolite is imbricated so the original succession is not preserved and therefore, the relative ages of the samples with respect to each other have not been established.

With three exceptions, all samples are tholeiitic basaltic in composition (Fig. 6a,b); the exceptions are three samples of andesite in the supracrustal part of the ophiolite which are transitional to calc-alkalic in affinity. In detail, the sample set can be divided into three geochemical suites, a light-rare-earth-element (LREE)-enriched suite, a non-LREE-enriched suite with Th/Nb ratios >1, and a non-LREE-enriched suite with Th/Nb ratios <1 (Fig. 6c-e). The LREE-enriched suite comprises mainly samples from the supracrustal part of the ophiolite; it is characterized by flat primitive-mantle normalized heavy-rare-earth-element (HREE) profiles with relatively sharp enrichments of Eu and lighter elements, and a Th/Nb ratio >>1. The non-LREE-enriched suites have generally flat primitive-mantle-normalized patterns and differ only in their Th/Nb ratios. The non-LREE-enriched suite with Th/Nb ratios <1 is enriched in concentrations of all trace-elements relative to average normal (NMORB) and enriched mid-ocean ridge (EMORB) compositions and have different patterns of enrichment relative to average ocean island basalts (OIB; Fig. 6f). When compared to the average compositions of different types of subduction-generated basalts, the non-LREE-enriched suite with Th/Nb >1 are more enriched in trace-element concentrations than a typical island arc tholeiite (IAT), but show some similarities to average LREE-enriched tholeiite (L-IAT; Fig. 6g) and with back-arc basin basalts (BABB) from the Lau Basin (Fig. 6g). The LREE-enriched suite is similar to calc-alkaline basalt typical of relatively mature island arcs (CAB; Fig. 6h).

TRIASSIC GABBRO

Twenty samples of Triassic gabbro were analyzed. All samples are basaltic in composition with tholeiitic to transitional affinities (Fig. 7a,b). All samples are generally rare-earth-element-enriched relative to primitive mantle (Figs. 7c,d) and are slightly more enriched in the lighter rare-earth elements. Two suites are apparent in the trace-element patterns, one with a Th/Nb ratios <1 and the other with Th/Nb ratios >1. When compared with the trace-element compositions of basalts from modern tectonic settings, the Th/Nb <1 suite most strongly

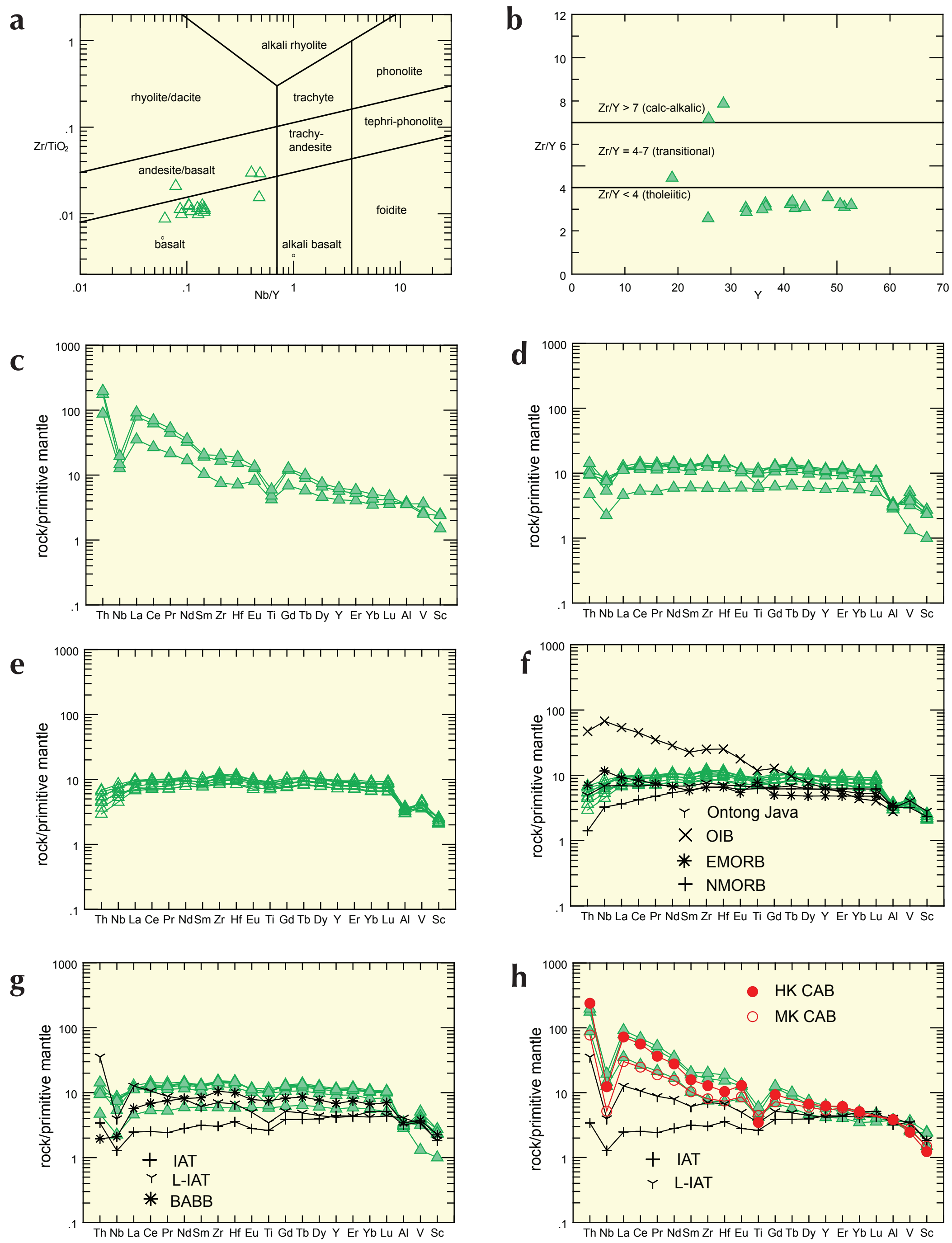

Figure 6. *(opposite page) Trace-element geochemical characteristics of diabase and foliated greenstone from the Harzburgite Peak – Eikland Mountain ophiolite.* ***(a)*** *A revised Winchester-Floyd composition diagram (Winchester and Floyd, 1977); and* ***(b)*** *Zr/Y vs. Y diagram (Barrett and McLean, 1999).* ***(c-h)*** *Primitive mantle–normalized trace-element plots (values for primitive mantle from Sun and McDonough, 1989):* ***(c-e)*** *three suites from Harzburgite Peak – Eikland Mountain ophiolite; and* ***(f-h)*** *three suites compared with basalts from modern tectonic settings. OIB = ocean island basalt; EMORB = enriched mid-ocean basalt; NMORB = normal mid-ocean ridge basalt; IAT = island arc tholeiite; L-IAT = light rare-earth-element-enriched island arc tholeiite; BABB = back-arc basin basalt; HK CAB = high potassium calc-alkaline basalt; MK CAB = medium potassium calc-alkaline basalt. OIB, EMORB, NMORB values are from Sun and McDonough (1989). IAT values are from Piercey (2001) and Piercey et al. (2004). L-IAT values are from Shinjo et al., 2000. BABB values are from Ewart et al. (1994) and CAB, from Stoltz et al. (1990). See text for discussion.*

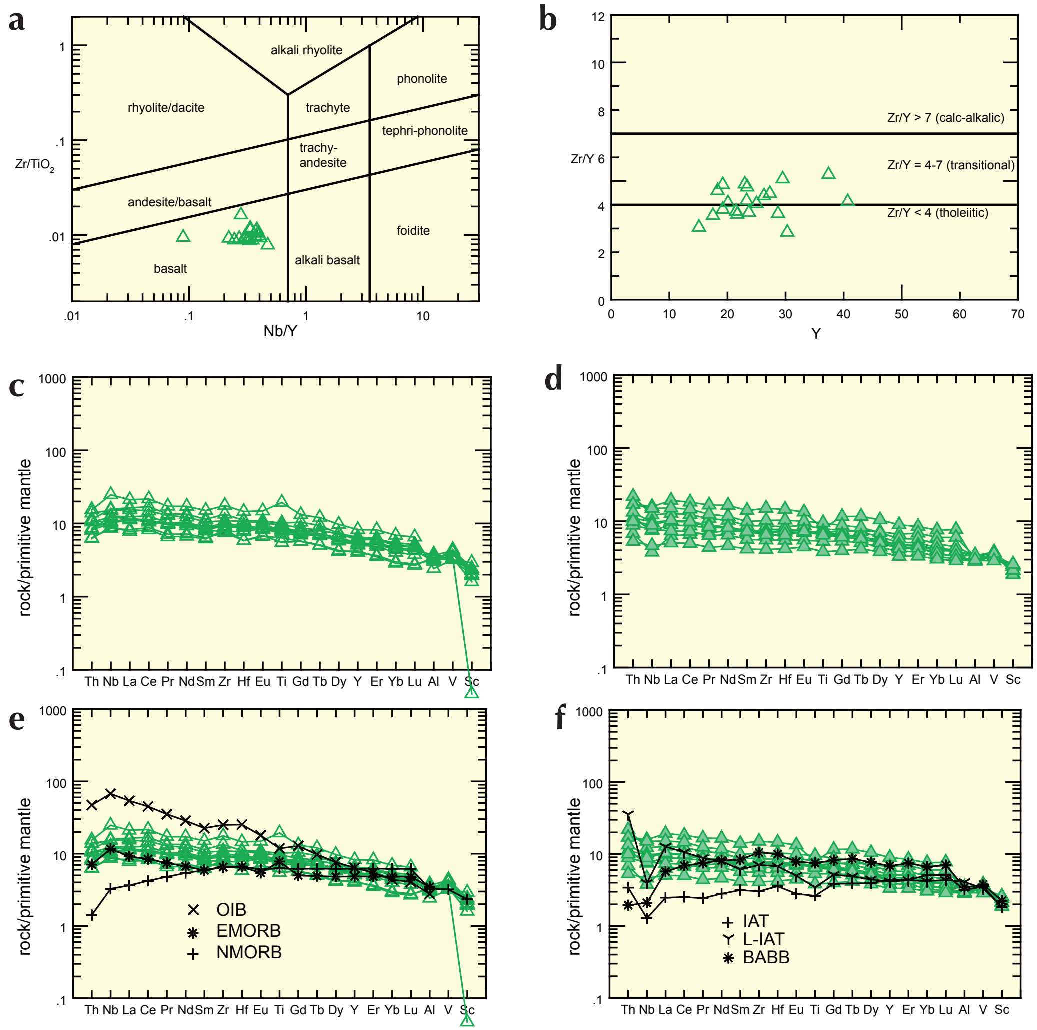

Figure 7. *Trace-element geochemical characteristics of late Middle Triassic gabbro.* ***(a)*** *A revised Winchester-Floyd composition diagram (Winchester and Floyd, 1977);* ***(b)*** *Zr/Y vs. Y diagram (Barrett and McLean, 1999).* ***(c-h)*** *Primitive mantle-normalized trace-element plots:* ***(c-e)*** *two suites defined by trace-element plots;* ***(f-h)*** *two suites compared with basalts from modern tectonic settings. Primitive mantle values from Sun and McDonough (1989) and abbreviations as in Figure 6. See text for discussion.*

resembles an EMORB composition, although generally more enriched in all the trace-elements (Fig. 7e). The Th/Nb >1 suite, as with one of the Harzburgite Peak – Eikland Mountain ophiolite suites, resembles compositions from modern arc settings (Fig. 7f).

DISCUSSION

The analytical data presented herein bear directly on the age, correlation, mineral potential and paleo-tectonic settings of the different subdivisions of 'Windy-McKinley' terrane.

U-Pb crystallization ages for the White River formation and the gabbro bodies intruding the schist subdivision of 'Windy-McKinley' terrane are identical to U-Pb age determinations for felsic metavolcanic rocks (Dusel-Bacon *et al.*, 2006; Dashevsky *et al.*, 2003) and gabbro (Dashevsky *et al.*, 2003) in the Delta district in the eastern Alaska Range located along strike approximately 150 km west-northwest of the Yukon-Alaska border. The new data presented here lend substance to the correlation between the areas proposed by Murphy *et al.* (2008). The White River formation is coeval with the Drum unit of the Delta District which hosts several volcanogenic massive sulphide (VMS) deposits, hence our new age data are metallogenically significant.

The new detrital zircon data forms the basis of a tentative stratigraphic interpretation and correlations for the schist subdivision of 'Windy-McKinley' terrane. The presence of a single Early Mississippian detrital zircon in the Scottie Creek formation implies an Early Mississippian or younger age. This single grain, although preliminary and in need of corroboration, suggests that the Scottie Creek formation stratigraphically overlies the Late Devonian White River formation. Furthermore, it invites correlation with the lithologically similar Tok River unit of the Delta district which overlies the Drum unit (Dashevsky *et al.*, 2003). The lower grade of metamorphism and lower degree of deformation of the Mirror Creek formation relative to both the Scottie Creek or White River formations, and its detrital zircon modes younger than those of the Scottie Creek formation, suggest that the Mirror Creek formation is stratigraphically younger than the Scottie Creek formation. We tentatively correlate the Mirror Creek formation with the lithologically similar upper part of the Hayes Glacier belt of the Delta District, which overlies the Jarvis belt containing the Drum and Tok River units (Dashevsky *et al.*, 2003).

The rocks of the Delta District have traditionally been correlated westwardly with sequences in the Alaska Range. Nokleberg *et al.* (1992) correlated the Late Devonian felsic meta-volcanic-bearing rocks of the Jarvis belt with coeval rocks in the Bonnifield District in the northern Alaska Range and the Hayes Glacier belt, with similar rocks in the central Alaska Range south of the Hines Creek fault. Wilson *et al.* (1998) correlated rocks south of the Hines Creek fault with the Upper Devonian Yanert Fork sequence and the depositionally overlying Upper Triassic unit Trcs of the Healy quadrangle to the west (Csetjey *et al.*, 1992; Pingston terrane of Jones *et al.*, 1982); all of these units are voluminously and extensively intruded by gabbro and diabase. Dusel-Bacon *et al.* (2006) correlated the rocks of the Delta District with the Bonnifield District and interpreted them both as being part of the para-autochthonous North American continental margin.

Owing to the notable absence of bodies of gabbro in the Bonnifield District, we favour a correlation of the schist-gabbro assemblages of the Delta District and the 'Windy-McKinley' terrane with the Yanert Fork sequence and unit Trcs in the central Alaska Range south of the Hines Creek fault, rather than with the para-autochthonous North American continental margin rocks of the Bonnifield District. This correlation defines a belt of rocks that superficially resembles both the allochthonous Yukon-Tanana terrane and the rocks of the para-autochthonous North American continental margin, but differs in key ways. The presence of voluminous late Middle Triassic gabbro distinguishes the 'Windy-McKinley' belt lithologically from nearby parts of Yukon-Tanana terrane and implies an Early Mesozoic history distinct from the Yukon-Tanana terrane. Detrital zircon age spectra from the Scottie Creek and Mirror Creek formations differ from both nearby Yukon-Tanana terrane and para-autochthonous North American margin spectra in their large populations of 1.0 to 1.6 Ga zircons, and in the case of the Mirror Creek formation, significant Neoproterozoic, Cambrian and Silurian zircon populations (Nelson and Gehrels, 2007; Bradley *et al.*, 2007, 2008; Dusel-Bacon, pers. comm., 2008; Fig. 5). These latter ages are common in rocks of the Insular terranes (Bradley *et al.*, 2007; Colpron and Nelson, in press), suggesting that they may be a possible source for the Mirror Creek formation.

Lithological and detrital zircon differences notwithstanding, the 'Windy-McKinley' belt could still be of Laurentian affinity, or in part, a post-amalgamation sequence overlapping terranes of the Laurentian and Insular realms. Late Middle Triassic gabbro sills intrude para-autochthonous North American rocks of the Tombstone thrust sheet in western Yukon (Tempelman-Kluit, 1970; Thompson *et al.*, 1992; Mortensen and Thompson, 1990), as well as the correlative Beaver Creek thrust sheet in Alaska, north of Fairbanks (Weber *et al.*, 1992; Tempelman-Kluit, 1984; Gabrielse *et al.*, 2006; Mortensen, unpublished data). Relatively minor populations of 1.0 to 1.6 Ga zircons occur locally in Yukon-Tanana terrane, as well as in autochthonous and para-autochthonous rocks of the North American continental margin (Wickersham grit of Alaska and correlative Hyland Group of Yukon, Ross *et al.*, 2005; Bradley *et al.*, 2007, 2008). The source of these zircons is not known. Basement rocks of this age are not exposed in the northern Cordillera, but they have been inferred to be in the subsurface based on occurrences of clasts containing zircons of that age found in diatremes (Jefferson and Parrish, 1989; Milidragovic, 2008). Neoproterozoic, Cambrian and Silurian zircons in the Mirror Creek formation were likely derived from the non-Laurentian Insular terranes, which make up most of northern, western and southern Alaska, and southwestern Yukon (Bradley *et al.*, 2007); some of these terranes were sutured to northwestern Laurentia as early as Middle Devonian (Lane, 2007; Colpron and Nelson, in press). Till *et al.* (2007) and Csetjey *et al.* (1992) documented depositional contacts of unit Trcs with the para-autochthonous continental margin sequence in the Kantishna Hills west of the Bonnifield District, and with the Yanert Fork sequence between the Hines Creek and McKinley strands of the Denali fault. In the westernmost part of the area between the Hines Creek and McKinley strands, unit Trcs is located near, but in unknown relationship with, the Farewell terrane. The Yanert Fork sequence and unit Trcs also occur south of the McKinley strand, near the northernmost exposures of the Insular superterrane. The Mirror Creek formation and westwardly correlative Upper Triassic clastic rocks of unit Trcs could therefore be an overlap sequence onto rocks of both Laurentian (Yukon-Tanana terrane and para-autochthonous North American margin rocks of Yukon-Tanana upland) and non-Laurentian origin.

The geochemical data from the late Middle Triassic gabbro and the Harzburgite Peak – Eikland Mountain ophiolite provide some insight into the paleo-tectonic setting(s) of the magmatic episode(s). When compared with modern basaltic rocks from well constrained tectonic settings, the trace-element geochemical character of both the late Middle Triassic gabbro and, in particular, the ophiolite, is most like the geochemical character of rocks from suprasubduction zone settings (*e.g.,* Shervais and Metcalf, 2003). Each episode has one suite that resembles either NMORB or EMORB compositions, but is overall more enriched across the spectrum of rare-earth elements. Another suite having Th/Nb >1 resembles LREE-enriched island arc tholeiites and back-arc basin basalts. When plotted on a Th/Yb versus Nb/Yb diagram (Pearce and Peate, 1995), the Triassic gabbro samples plot in a cluster around the EMORB composition, but offset from the mantle enrichment array in the direction of subduction zone enrichment (Fig. 8). Similarly, the ophiolite samples plot in a cluster around the primitive mantle and NMORB compositions, but are also offset in the direction of subduction zone enrichment. The exceptions are the three samples of andesitic composition from the supracrustal levels of the ophiolite which plot with upper continental crust values; this composition may reflect crustal contamination. Although not conclusive, all of these characteristics suggest a suprasubduction zone setting for both the Triassic gabbro and the ophiolite.

The geochemical data from the ophiolite provides some support for its correlation with parts of the Chulitna terrane (Jones *et al.*, 1982; Clautice *et al.*, 2001), a suprasubduction zone ophiolite located in the southern Alaska Range south of the Denali fault (Murphy, 2007). Doubt was shed on this correlation by Murphy *et al.* (2008) on the basis of the non-arc-like geochemical characteristics of a small set of samples from the ophiolite; our more comprehensive sampling has revealed a more arc-like character, thereby permitting a correlation with the Chulitna terrane. If correlative, the Harzburgite Peak – Eikland Mountain ophiolite would then be Devonian to Permian in age and therefore older than the Triassic gabbro intruding the schist subdivision, further implying that the Harzburgite Peak – Eikland Mountain ophiolite and Triassic gabbros formed above different subduction zones. Geochronological data from the ophiolite are necessary to establish the age of the ophiolite before its correlation and relationship with the Triassic gabbro can be further evaluated.

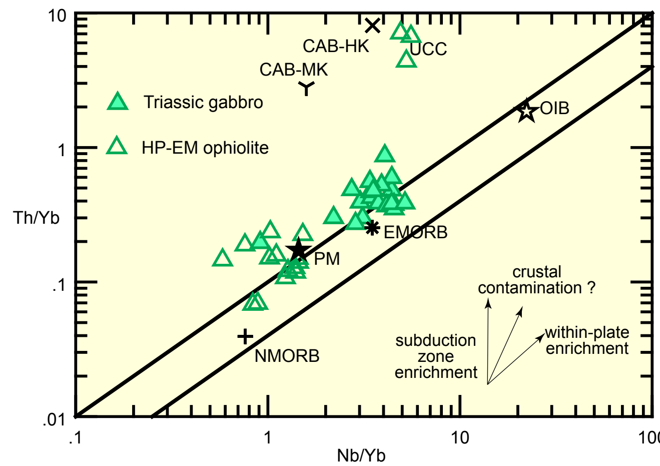

Figure 8. *Th/Yb vs. Nb/Yb diagram (Pearce and Peate, 1995) comparing samples of Triassic gabbro with those from the Harzburgite Peak – Eikland Mountain ophiolite (HP-EM ophiolite). The plot illustrates enrichments due to subduction zone processes and/or contamination. Abbreviations as in Figure 6. See text for discussion.*

CONCLUSIONS

1. New ages from the felsic metavolcanic rocks and gabbro of 'Windy-McKinley' terrane substantiate the proposed correlation of these rocks with the rocks of the Delta District, Alaska. This correlation makes the 'Windy-McKinley' terrane prospective for volcanogenic massive sulphide deposits.
2. Detrital zircon data from the different formations of the schist-gabbro subdivision, and the difference in degree of deformation and metamorphism between the Mirror Creek and other formations of the subdivision, suggest that the Late Devonian White River formation is overlain by the Scottie Creek formation followed by the Mirror Creek formation. This stratigraphic succession is similar to that of the Delta District, further supporting the proposed correlation.

3. The correlation of the Delta District can be extended westward to include rocks between the Hines Creek and McKinley strands of the Denali fault, the Yanert Fork sequence and Pingston terrane. This belt of 'Windy-McKinley'-like rocks is distinguished from rocks of the para-autochthonous part of Yukon-Tanana terrane to the north with which they were originally correlated, on the basis of voluminous late Middle Triassic mafic magmatism and differences in detrital zircon characteristics.
4. The trace-element geochemical character of Triassic gabbro of the schist-gabbro subdivision and mafic rocks of the Harzburgite Peak – Eikland Mountain ophiolite suggest a suprasubduction zone setting for both.
5. A suprasubduction zone setting for the Harzburgite Peak – Eikland Mountain ophiolite permits a proposed correlation with disrupted ophiolitic rocks of the Chulitna terrane. If correlative, the Harzburgite Peak – Eikland Mountain ophiolite would be mid-Paleozoic in age. The Triassic gabbro would therefore have formed above a younger subduction zone.

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