TECTONIC EVOLUTION OF THE CHUGACH-PRINCE WILLIAM TERRANE IN PRINCE WILLIAM SOUND AND KODIAK ISLAND, ALASKA

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INTRODUCTION AND OVERVIEW

The southern Alaskan continental margin is comprised of a collage of Mesozoic and Cenozoic terranes with a late Tertiary overprint related to the active motion between the Pacific plate and North America (Plafker et al., 1989; 1994; Enklemann et al., 2010). Our focus here is on the Chugach and Prince William terrane (CPW), which is a regionally extensive accretionary complex between the relatively static elements of the inboard Wrangellia composite terrane and the active components of the modern accretionary complex and the colliding Yakutat microplate (Fig. 1; Enklemann et al., 2010).

The Chugach-Prince William (CPW) terrane is a Mesozoic-Tertiary accretionary complex well exposed for ~2200 km in southern Alaska and is inferred to be one of the thickest accretionary complexes in the world (Plafker et al., 1994). The CPW can be divided into an inboard mesomélange and a younger outboard flysch facies with associated basaltic rocks (Amato and Pavlis, 2010). The bulk of the Chugach terrane (>90%) is the outboard flysch assemblage, which is comprised of Upper Cretaceous to Eocene deep-water turbidites with abundant quartzofeldspathic and volcanic-lithic sandstones with structurally and depositionally interleaved basaltic rocks. In Prince William Sound, the flysch is subdivided between the inboard Upper Cretaceous Valdez group north of the Contact fault, and the outboard Paleocene and Eocene Orca group. On Kodiak Island, the flysch is subdivided into the inboard Upper Cretaceous Kodiak Formation, and outboard Paleocene Ghost Rocks and Sitkalidak Formations.

Together, the flysch of the CPW represents a thick sequence of deformed Campanian to Eocene turbidites and minor volcanic rocks inferred to represent the accumulation of material in a near-trench setting. Several slices of ophiolites occur in the CPW terrane, including the 57 Ma Resurrection Peninsula and Knight Island sequences (Nelson et al., 1989). These ophiolites appear to have formed in a supra-subduction zone setting during deposition of the clastic sediments of the Orca Group, they were then accreted to the margin soon after formation, and finally they were intruded by the Sanak-Baranof belt (SBB) of granite plutons (Tydsal and Case, 1979; Bradley et al., 2006). The SBB plutons are an interesting and important part of the CPW story because these near-trench intrusions are inferred to represent melts of the accretionary complex due to ridge-trench interaction and this interaction was diachronous from west (Sanak Island) to east (Baranof Island) over a distance of about 2100 km. A distinctive attribute of Prince William Sound is that these rocks were intruded by a second suite of plutons, the Eshmay Suite, which are more localized, but poorly dated to the Late Eocene or younger.

ANALYTICAL OVERVIEW

Our work targeted the age and thermal history of the sedimentary units, and the geochemistry and paleomagnetism of igneous rocks of the CPW terrane (Figure 2). A large fraction of our effort focused on understanding the provenance and thermal history of the Campanian to Eocene flysch in Prince William Sound (mainly the Orca Group, but also the Valdez Group), and correlative rocks on Kodiak Island (Kodiak, Ghost Rocks, Sitkalidak). Using single grain U/Pb dating, we dated 2786 zircon grains from these sedimentary units; these dates include several hundred grains that were pre-screened and selected as potential Precambrian zircons (see Hilbert-Wolf, this volume, Olivas, this volume; Carlson, this volume). We double dated (U/Pb and ZFT) 100 grains from the youngest, most outboard rocks on Montague Island.

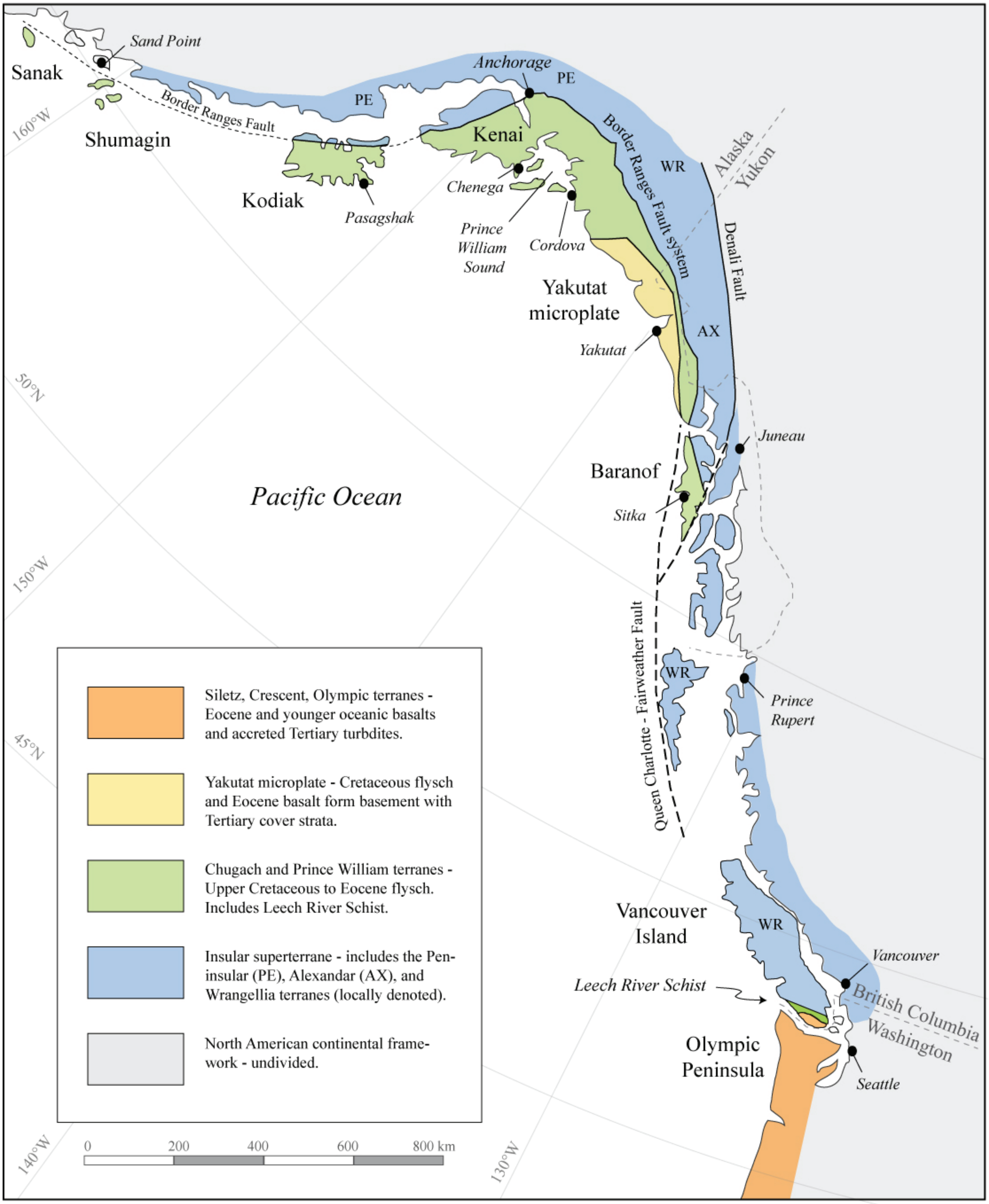

Figure 1: Simplified map showing primary tectonostratigraphic elements of southern Alaska and the Pacific Northwest (modified form Cowan, 2003).

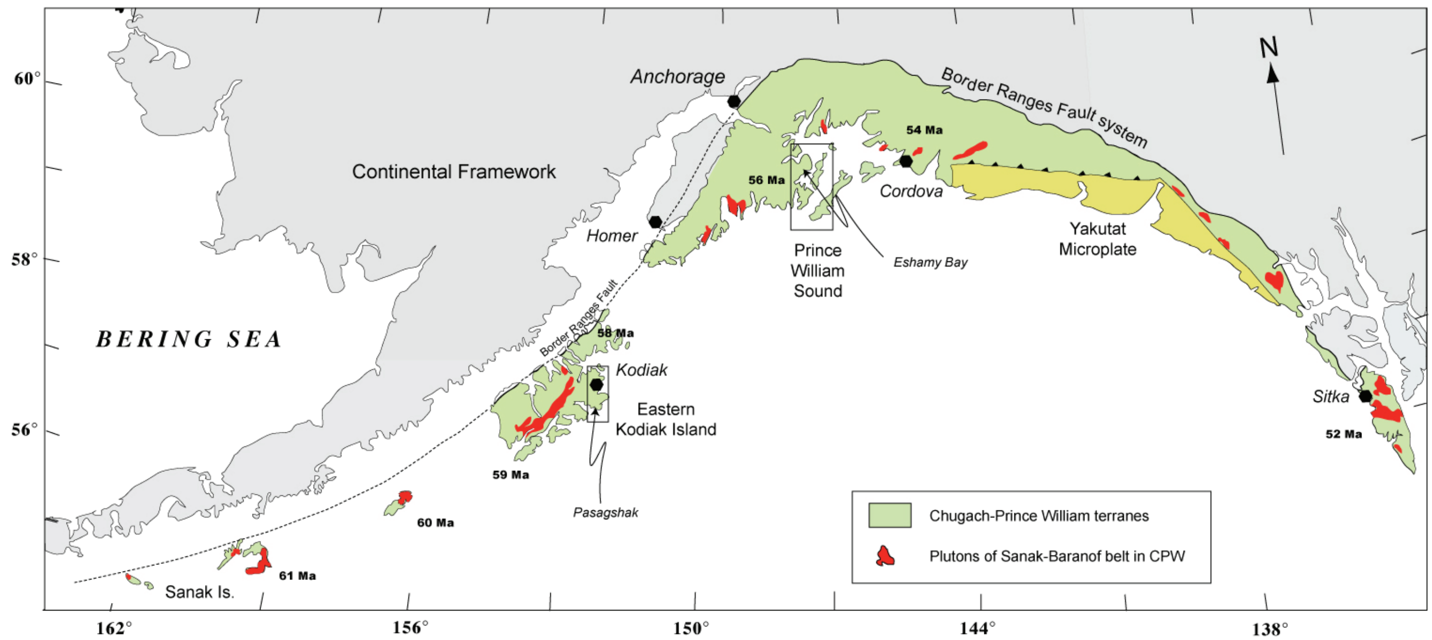

Figure 2: Map of southern Alaska showing the distribution of rocks in the Chugach-Prince William terranes (green) and the Yakutak microplate, which is actively colliding with Alaska. The two primary study areas from 2010 are indicated on Kodiak Island (Pasagshak) and in western Prince William Sound (Eshamy Bay).

We also successfully dated six plutons in Prince William Sound and the newly determined age range of these plutons is now narrowly constrained (Johnson, this volume). Our data set includes 400 new single fission track ages centered on rocks in the Prince William Sound area (Carlson, this volume). For our paleomagentic study on the Knight Island ophiolite and nearby Eshamy pluton, we collected samples from 25 sites and had mixed results (Espinosa, this volume). For geochemistry, we used traditional petrography and collected major and trace element data (XRF) from 25 samples from the Knight Island ophiolite and associated basaltic rocks (Miner, this volume), and 22 samples from the Late Eocene Eshamy suite of granite plutons (Johnson, this volume).

PRIMARY FINDINGS

Our work has made significant progress toward understanding the age of sedimentary units, their thermal history, and the origin and source of igneous rocks. Our primary findings include the following:

1) Age and provenance of flysch of the Paleocene to Eocene Orca Group. Hannah Hilbert-Wolf (Carleton College) determined the maximum depositional age of the Orca flysch along a transect in western Prince William Sound using U/Pb detrital zircon ages from ten locations (about 1500 zircons). The maximum depositional ages of flysch of the Orca Group ranges from 69 to 35 Ma, NW to SE, suggests that the bulk of the flysch (Valdez+Orca) of CPW terrane was more or less deposited continuously from ~85 Ma to ~35 Ma with only a few potential age gaps. Forty-two zircons from the preliminary data set are Precambrian, with modes at 1164, 1826, 1912, and 1988 Ma.

A major finding from this work is that we can now divide the Paloecene-Eocene Orca Group into three distinct units or belts based on maximum depositional age (U/Pb) and thermal history (Carlson, this volume). The Orca Group consists of: [A] the inboard Whale Bay – Bainbridge belt (Paleocene to earliest Eocene), which is in fault contact with the Valdez Group and has maximum depositional ages < 57-58 Ma. This belt was accreted, intruded by, and regionally metamorphosed to greenshist grade by the 54 Ma SBB plutons and ~38 Ma Eshamy suite plutons (Johnson, this volume); [B] the more outboard Latouche belt (Middle Eocene) which includes rocks on Evans and Latouche Islands, has maximum depositional ages <38-40 Ma, and was intruded and metamorphosed to lower greenschist grade by ~38 Ma Eshamy suite plutons; and [C] the outboard Montague belt (Upper Eocene) deposited < 35 Ma, and is essentially unmetamorphosed (Tysdal and Case, 1979; Carlson, this volume)

The maximum depositional ages constrained by this study in combination with field observations suggest that the Orca Group was deposited contemporaneously with the intrusion of the flysch by near trench plutons of the Sanak Baranof belt and of the Eshamy suite (Johnson, this volume). One interesting finding is that the Latouche belt must have been deposited, accreted, and intruded in a narrow window at 37-40 Ma (unresolvable within analytical uncertainty of U/Pb and ZFT). The detrital U-Pb data also support along-strike correlations between the Late Cretaceous to Eocene formations on Kodiak Island and those in Prince William Sound.

2) Age and provenance of clastic units on Kodiak Island. Sarah Olivas (UTEP) analyzed six detrital zircon samples from a transect across the accretionary complex on Kodiak Island and reports on 782 single grain U/Pb ages. She collected samples from the Maastrictian Kodiak Formation, Paleocene Ghost Rocks Formation, Eocene Sitkalidak Formation, and the unconformably overlapping Miocene Narrow Cape Formation. The Kodiak Formation is most distinctive because it has a relative abundance of Precambrian ages that primarily range from 1200 Ma to 2300 Ma. The abundance of Precambrian grains decreases sharply in younger more outboard units. The Ghost Rocks contains a much narrower spectrum of grain ages with the bulk at 66 ± 4 Ma and much fewer Precambrian grains (1038 to 1517 Ma).

Based on maximum depositional ages, the U/Pb zircon data suggest that the Ghost Rocks in Ugak Bay are more closely allied with the Paleocene to earliest Eocene Orca Group (Whale Bay- Bainbridge Island belt from above) because the young U/Pb ages in Ghost Rocks (63 Ma) are younger than what has been recognized for the Valdez Group (68 Ma or older) and is statistically similar to the young ages in the older part of the Orca Group (61 to 68 Ma) (Hilbert-Wolf, this volume).

3) Thermal history of the CPW flysch in Prince William Sound. Ben Carlson (Union College) used zircon fission track (ZFT) dating to work out the thermal history of the flysch along the same transect used by Hilbert-Wolf (this volume). Almost all rocks of the CPW in Prince William Sound experienced greenschist to prehnite-pumpellyite grade metamorphism, and a major discovery from this work is that these rocks experienced two peak thermal metamorphic events that ended at c. 50 Ma and c. 36-40 Ma, both coincident with the now well-dated plutonism (Johnson, this volume). The most outboard, and youngest accreted rocks of the Montague belt (<35 Ma, Hilbert-Wolf, this volume) are unmetamorphosed and preserve ZFT cooling ages from the source terranes of the flysch. In the rearward part of the wedge, rocks of the Valdez Group near Anchorage show only minor heating and thermal resetting at c. 50 Ma; these new data suggest that, at least locally, rearward parts of the accretionary complex have resided relatively high in the crust following accretion.

4) Eshamy suite plutons. Emily Johnson (Whitman College) worked on the age and origin of the Eshamy suite of granitoid plutons that intrude the Orca and Valdez flysch in western Prince William Sound. New U/Pb zircon dates for five of the Eshamy suite plutons yield concordant dates between 37.6 ± 0.5 and 39.9 ± 0.7 Ma. Johnson also reports a 54.5 ± 1.8 Ma U/Pb zircon dates for the Sheep Bay pluton of the Sanak-Baranof belt from eastern Prince William Sound. The ~37-40 Ma Eshamy suite intrusives correspond to a short-lived intense thermal anomaly that is now well recognized in the ZFT cooling ages (Carlson, this volume). The major and trace element geochemistry of the Eshamy Bay and the Nellie Juan plutons show that these plutons: 1) do not have a strong MOR signature; 2) are not compositionally similar to synchronous adakites in the Caribou Creek Volcanic Field (CCVF) ~ 200 km north (Cole et al., 2006); 3) have a similar whole-rock geochemistry to sediments of the Orca Group; and 4) have trace element chemistry similar to synchronous rhyolites of the CCVF. These results support a cogenetic relationship between the CCVF rhyolites and PWS plutons.

5) Knight Island ophiolite (KIO). Steven Espinoza (UTEP) and Lucy Miner (Macalester College) worked on the paleomagnetism and geochemistry of the Knight Island ophiolite, respectively. The Knight Island ophiolite, mapped as part of the Orca Group in Prince William Sound, is a spectacular sequence of sheeted dikes, pillow basalts, and interbedded clastic sediments that is likely a companion to the better studied ~57 Ma Resurrection Peninsula ophiolite (Nelson et al., 1987; Bradley et al., 2006 and references therein). Miner (this volume) focused on the major and trace element geochemistry of the sheeted dikes and associated pillow basalts, as well as other basaltic rocks in the Orca Group on Chenega Island. Major element geochemistry from the KIO reinforces earlier speculations of the similarity between Knight Island and Resurrection Peninsula (cf. Lytwyn et al., 1997; Nelson and Nelson 1992). An interesting finding from this work suggests that the Chenega Island volcanics are distinct from those directly affiliated with Knight Island. Miner (this volume) also shows that the Orca volcanic rocks (KIO and Chenega Island) are enriched in incompatible elements compared to N-MORB suggesting a contaminated mantle source. She modeled fractional crystallization and magma mixing model between the most primitive basalt compositions and the Orca flysch to help explain some of the compositional variation present in the trace element chemistry of the Orca volcanics.

Espinoza (this volume) reports preliminary paleomagnetic results from 83 cores collected at 11 sites from the Knight Island ophiolite and Eshamy suite plutons. The preliminary data confirms that samples from the sheeted dike complex appear to be affected by a strong thermal or chemical overprint identified in previous paleomagnetic studies on the pillow basalts from the northern part of Knight Island (Bol, 1993). This overprinting is likely related to the thermal events recorded in the ZFT results reported by Carlson (this volume).

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REFERENCES

Bradley, D., and Miller, M., 2006, Field guide to south-central Alaska's accretionary complex, Anchorage to Seward: Alaska Geological Society Field Guide Series, Anchorage, Alaska, 32 p.

Bradley, D., Haeussler, P., O'Sullivan, P., Friedman, R., Till, A., Bradley, D., and Trop, J., 2009, Detrital zircon geochronology of Cretaceous and Paleogene strata across the south-central Alaska convergent margin, in Haeussler, P.J., and Galloway, J.P., Studies by the U.S. Geological Survey in Alaska, 2007: U.S. Geological Survey Professional Paper 1760-F, 36 p.

Coney, P.J., Jones, D.L., and Monger, J.W.H., 1980, Cordilleran suspect terranes: Nature, v. 288, p. 329–333.

Carlson, B.M., 2012 (this volume), Cooling and provenance revealed through detrital zircon fission track dating of the Upper Cretaceous Valdez Group and Paleogene Orca Group in Western Prince William Sound, Alaska; Proceedings from the 25th Keck Geology Consortium Undergraduate Research Symposium, Amherst MA.

Cole, R. B., and Stewart, B. W., 2009, Continental margin volcanism at sites of spreading ridge subduction: Examples from southern Alaska and western California: Tectonophysics, v. 464, no. 1-4, p. 118-136.

Cole, R. B., Nelson, S. W., Layer, P. W., and Oswald, P. J., 2006, Eocene volcanism above a depleted mantle slab window in southern Alaska: Geological Society of America Bulletin, v. 118, no. 1-2, p. 140-158.

Cowan, D.S., 2003, Revisiting the Baranof-Leech River Hypothesis for Early Tertiary Coastwise Transport of the Chugach-Prince William Terrane: Earth and Planetary Science Letters, no. 213, p. 463-475.

Davidson, C., Garver, J.I., Hilbert-Wolf, H.L., and Carlson, B. 2011, Maximum depositional age of the Paleocene to Eocene Orca Flysch, Prince William Sound, Alaska, Geological Society of America Abstracts with Programs, v. 43, n. 5, p. 439.

Enkelmann, E., Zeitler, P.K., Garver, J.I., Pavlis, T.P. and Hooks, B.P, 2010. The thermochronological record of tectonic and surface process interaction at the Yakutat–North American collision zone in southeast Alaska; Am. J. of Sci., v. 310, p. 231-260.

Espinosa, S., 2012 (this volume), Paleomagnetism of the Knight Island Ophiolite, Southern Alaska; Proceedings from the 25th Keck Geology Consortium Undergraduate Research Symposium, Amherst MA.

Evenson, N.S., 2010, U-Pb detrital zircon geochronology and provenance of the Tertiary Kootznahoo Formation, southeastern Alaska: A sedimentary record of Coast Mountains exhumation [BA thesis]: Carleton College, 72 p.

Farmer, G.L., Ayuso, R., and Plafker, G., 1993, A Coast Mountains provenance for the Valdez and Orca groups, southern Alaska, based on Nd, Sr, and Pb isotopic evidence: Earth and Planetary Science Letters, v. 116, p. 9-21.

Garver, J.I., Davidson, C., Izykowski, T.I., Milde, E.R., 2011, Thermal evolution of flysch of the Chugach Prince William terranes, eastern Prince William Sound, Alaska, Geological Society of America Abstracts with Programs, v. 43, n. 5, p. 553.

Haeussler, P.J., Bradley, D.C., Wells, R.E., and Miller, M.L., 2003, Life and Death of the Resurrection Plate: Evidence for its Existence and Subduction in the Northeastern Pacific in Paleocene-Eocene Time: GSA Bulletin, v. 15, no. 7, p. 867-880

Helwig, J., and Emmet, P., 1981, Structure of the Early Tertiary 1 Orca Group in Prince William Sound and some implications for the plate tectonic history of southern Alaska: Journal of the Alaska Geological Society, v. 1, p. 12-36

Hilbert-Wolf, H.L., 2012 (this volume), A U/Pb detrital zircon provenance of the flysch of the Paleogene Orca Group, Chugach-Prince William terrane, Alaska; Proceedings from the 25th Keck Geology Consortium Undergraduate Research Symposium, Amherst MA.

Izykowski, T.M., Milde, E.R., and Garver, J.I., 2011, Fission-track dating of reset detrital zircon from the Vladez Group (Thompson Pass) and Orca Group (Cordova): Implications for the thermal evolution of the Chugach-Prince William terrane, Alaska, Geological Society of America Abstracts with Programs, v. 43, n. 4, p. 81

Johnson, E., 2012 (this volume), Origin of Late Eocene granitiods in western Prince William Sound, Alaska; Proceedings from the 25th Keck Geology Consortium Undergraduate Research Symposium, Amherst MA.

Kochelek, E., Amato, J.M., Pavlis, T.L., and Clift, P.D., 2011, Flysch deposition and preservation of coherent bedding in an accretionary complex: Detrital zircon ages from the Upper Cretaceous Valdez Group, Chugach terrane, Alaska: Lithosphere, v. 3, no. 4, p. 265-274.

Kveton, K.J., 1989, Structure, thermochronology, provenance, and tectonic history of the Orca

Group in southwestern Prince William South, Alaska [Ph.D. thesis]: University of Washington, 184 p.

Lytwyn, J., Casey, J., Gilbert, S., and Kusky, T., 1997, Arc-like mid-ocean ridge basalt formed seaward of a trench-forearc system just prior to ridge subduction: An example from subaccreted ophiolites in southern Alaska: Journal of Geophysical Research, v. 102, no. B5, p. 10225-10243.

Madsen, J. K., Thorkelson, D. J., Friedman, R. M., and Marshall, D. D., 2006, Cenozoic to Recent plate configurations in the Pacific Basin: Ridge subduction and slab window magmatism in western North America: Geosphere, v. 2, no. 1, p. 11.

Milde, E.R., 2011, Fission track ages of detrital zircon for the Campanian-Maastrichtian Valdez Group of the Chugach terrane, Richardson Highway, Valdez, southeast Alaska. Unpublished undergraduate thesis, Union College, Schenectady, NY, 78 p.

Miner, L. 2012 (this volume), Geochemical analysis of Eocene Orca Group volcanics, Paleocene Knight Island Ophiolite, and Chenega Island volcanics in Prince William Sound, Alaska; Proceedings from the 25th Keck Geology Consortium Undergraduate Research Symposium, Amherst MA.

Nelson, S.W., M.L. Miller, and J.A. Dumoulin, 1989, Resurrection Peninsula Ophiolite, in Guide to the Geology of Resurrection Bay, Eastern Kenai Fjords Area, Alaska, Guidebook, edited by S.W. Nelson and T.W. Hamilton, pp. 10-20, Geol. Soc. of Alaska, Anchorage.

Nelson, S.W., and Nelson, M.S., 1993, Geochemistry of ophiolitic rocks from Knight Island, Prince William Sound, Alaska: U.S. Geological Survey Bulletin 2068, p. 130-142.

Olivas, S.J., 2012 (this volume),U/Pb detrital zircon study of the Upper Cretaceous to Miocene strata of Kodiak Island, Alaska; Proceedings from the 25th Keck Geology Consortium Undergraduate Research Symposium, Amherst MA.

Plafker, G., Moore, J.C., and Winkler, G.R., 1994, Geology of the southern Alaska margin, in Plafker, G., and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geol. Soc. of America, The Geology of North America, v. G-1, p. 389-449.

Tysdal, R.G., and Case, J.E., 1979, Geologic map of the Seward and Blying Sound quadrangles, Alaska: U.S. Geological Survey Miscellaneous Investigations Map I-1150, 12 p., scale 1:250,000.