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RESILIENCE OF ENDANGERED ACROPORA SP. CORALS IN BELIZE. WHY IS CORAL GARDENS REEF THRIVING?:
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TECTONIC EVOLUTION OF THE CHUGACH-PRINCE WILLIAM TERRANE, SOUTH CENTRAL ALASKA:
Faculty: CAM DAVIDSON, Carleton College, JOHN GARVER Union College
Students: KAITLYN SUAREZ, Union College, WILLIAM GRIMM, Carleton College, RANIER LEMPERT, Amherst College, ELAINE YOUNG, Ohio Wesleyan University, FRANK MOLINEK, Carleton College, EILEEN ALEJOS, Union College

EXPLORING THE PROTEROZOIC BIG SKY OROGENY IN SW MONTANA: METASUPRACRUSTAL ROCKS OF THE RUBY RANGE
Faculty: TEKLA HARMS, Amherst College, JULIE BALDWIN, University of Montana
Students: BRIANNA BERG, University of Montana, AMAR MUKUNDA, Amherst College, REBECCA BLAND, Mt. Holyoke College, JACOB HUGHES, Western Kentucky University, LUIS RODRIGUEZ, Universidad de Puerto Rico-Mayaguez , MARIAH ARMENTA, University of Arizona, CLEMENTINE HAMELIN, Smith College

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ANTARCTIC PLIOCENE AND LOWER PLEISTOCENE (GELASIAN) PALEOCLIMATE RECONSTRUCTED FROM OCEAN DRILLING PROGRAM WEDDELL SEA CORES:
Faculty: SUZANNE O'CONNELL, Wesleyan University
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HOLOCENE CLIMATIC CHANGE AND ACTIVE TECTONICS IN THE PERUVIAN ANDES: IMPACTS ON GLACIERS AND LAKES:
Faculty: DON RODBELL & DAVID GILLIKIN, Union College
Students: NICHOLAS WEIDHAAS, Union College, ALIA PAYNE, Macalester College, JULIE DANIELS, Northern Illinois University

GEOLOGICAL HAZARDS, CLIMATE CHANGE, AND HUMAN/ECOSYSTEMS RESILIENCE IN THE ISLANDS OF THE FOUR MOUNTAINS, ALASKA
Faculty: KIRSTEN NICOLAYSEN, Whitman College
Students: LYDIA LOOPESKO, Whitman College, ANNE FULTON, Pomona College, THOMAS BARTLETT, Colgate University

CALIBRATING NATURAL BASALTIC LAVA FLOWS WITH LARGE-SCALE LAVA EXPERIMENTS:
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Short Contributions— Tectonics of Prince William Terrane, AK Project

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PROVENANCE OF THE CHUGACH-PRINCE WILLIAM TERRANE, ALASKA, FOCUSING ON THE PALEOGENE ORCA GROUP, USING U-PB DATING OF DETRITAL ZIRCONS

WILLIAM E. GRIMM, Carleton College
Research Advisor: Cameron Davidson

INTRODUCTION

The Late Cretaceous to Early Tertiary Chugach-Prince William (CPW) terrane is exposed for approximately 2,200 km on the southern Alaskan continental margin (Garver and Davidson, 2014; Davidson and Garver, this volume). The outboard rocks of the CPW terrane consist of thick, km-scale sections of marine flysch (turbidites), and associated volcanic rocks (Plafker et al., 1994). The CPW terrane is also intruded by plutons that systematically young from Sanak Island in the west (61 Ma) to Baranof Island in the east (50 Ma). There are currently two principal hypotheses for the tectonic environment in which the CPW terrane formed: 1) the Baranof-Leech River hypothesis and 2) the Resurrection Plate hypothesis (Cowan, 2003; Haeussler et al., 2003). The Baranof-Leech River hypothesis states that the CPW terrane formed south of its present latitude and that it was transported to its present position after its formation by dextral strike-slip faulting along the Pacific-North American margin. The Resurrection Plate hypothesis posits that the CPW terrane formed essentially in its current location, and it includes an extra "Resurrection plate" that has been completely removed by subduction. Both hypotheses propose subduction of mid-oceanic ridges to account for the plutons and volcanics observed in the CPW terrane, but the two hypotheses differ in fundamental ways, including source of the CPW flysch.

This paper investigates the age relationships and provenance of the Orca Group in eastern Prince William Sound, Alaska, and of the CPW terrane in general, using U-Pb dating of detrital zircons. This study builds on the work of Hilbert-Wolf (2012), which investigated the Orca Group in western Prince William Sound. New U-Pb data show that the Orca Group in eastern Prince William Sound has maximum depositional ages in the range of 61 – 51 Ma, which is during the time interval of the inferred interaction of the CPW terrane with an oceanic ridge (Fig. 1). U-Pb detrital zircon data in combination with zircon fission track data show that the fault-bounded "belts" of Orca Group rocks defined by Hilbert-Wolf (2012) and Carlson (2012) in western Prince William Sound do not carry over into eastern Prince William Sound. Precambrian grains indicate a split northern-southern Laurentian source for the Orca Group, and thus these data may support a restoration of the CPW terrane to south of its present location during deposition and accretion in the Paleocene.

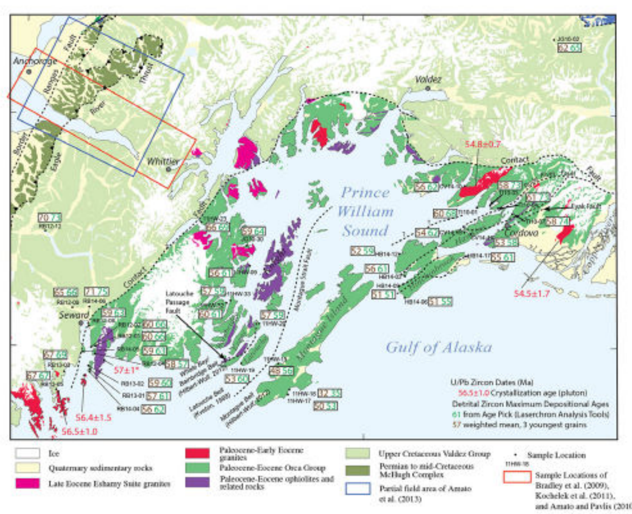

Figure 1. Geologic map of the Chugach-Prince William Terrane in western Prince William Sound, Alaska. Modified from Bradley and Miller (2006) and Kveton (1989). Detrital zircon U-Pb maximum depositional ages from this study, Hilbert-Wolf (2012), Frett (2014), Pettiette (2013), Bradley et al. (2009), Kochelek et al. (2011), Amato and Pavlis (2010), and Amato et al. (2013).

GEOLOGIC SETTING

The Orca Group chiefly comprises a flysch sequence of interbedded sandstones and shales (turbidites), with minor oceanic volcanic rocks, limestone, chert, and tuff (Plafker et al., 1994). Sandstones are quartzofeldspathic to feldspathic, with lesser components of lithic clasts (mainly volcanic-lithic, but also sedimentary), chert, and locally abundant areas of heavy minerals and biotite (Dumoulin, 1987). On the basis of paleontologic data and the age of cross-cutting plutons of the Sanak-Baranof belt, Plafker et al. (1985) assigned a Paleocene to early middle Eocene age for the Orca Group. However, Plafker et al. (1985) note that certain outboard localities show possibly Late Eocene to Early Oligocene ages, and Dumoulin (1987) suggests that because plutons do not intrude the southeast portion of the Orca Group, and because Middle and Late Eocene microfaunas exist in the southeast, that the Orca Group is Paleocene through Eocene. In addition, Hilbert-Wolf (2012) shows that the rocks of the Orca Group exposed along the southern margin of Montague Island have a maximum depositional age of 35 Ma (Upper Eocene) based on detrital zircon.

The Orca Group is isoclinally folded and imbricated, and is separated from the flysch of the Valdez Group of the Chugach terrane by the Contact fault to the north (Bol and Roeske, 1993; Plafker et al., 1994) (Fig. 1). Early mapping shows that there are three stratigraphic-structural belts within the Orca Group in western Prince William Sound, and that two of the three belts have seaward structural vergence, while the outermost "Montague belt" has landward structural vergence (Helwig and Emmet, 1981).

U-PB GEOCHRONOLOGY

Methods

Eight coarse-grained sandstone samples were collected from the Orca flysch in eastern Prince William Sound on Hawkins Island, Hinchinbrook Island, and the mainland near Cordova, Alaska (Fig. 1). Zircons were extracted from the samples by traditional methods of crushing and grinding, followed by separation with a Wilfly table or Rodgers table, heavy liquids, and a Frantz magnetic separator. U-Pb geochronology of zircons was conducted by laser ablation multicollector inductively coupled plasma mass spectrometry (LA-MC-ICPMS) at the Arizona LaserChron Center (Gehrels et al., 2006; 2008). In addition, five sandstone samples collected by Izykowski (2011) were also analyzed for U-Pb isotopes by LA-MC-ICPMS at the Arizona LaserChron Center (Fig. 1, samples beginning with "TI").

Several samples were "enhanced" with respect to Precambrian zircons. This method involves first splitting the zircon separate, setting aside one half for standard analysis using a random walk approach, and in the other half hand-picking grains that are thought to be of Precambrian age. Given proper composition, zircon crystals gradually accumulate color in a red-pink series through electron displacements driven by the α-decay of uranium and thorium, and accumulation of color is believed to be related to time since crystal cooling, uranium and thorium concentrations, and heavy rare earth element (HREE) concentration (Garver and Kamp, 2002). At near surface temperatures, Garver and Kamp (2002) note that zircons with typical compositions only accumulate color over 100s of millions of years, and so pink zircon color was one criterion used to select inferred Precambrian grains. However, Garver and Kamp (2002) note that controls of color generation in zircon need to be better understood, and thus grain roundedness was another criterion in selecting Precambrian grains, because older grains are inferred to have traveled and been physically abraded more.

RESULTS

All thirteen samples show three significant Phanerozoic grain-age populations, which include a dominant Late Cretaceous – Paleocene peak, a Jurassic peak, and a Devonian – Carboniferous peak (Fig. 2). Some samples exhibit minor grain-age populations on either side of the Devonian – Carboniferous peak (e.g., minor peaks in the Ordovician, Silurian, and Permian). In all samples, the Devonian – Carboniferous populations have the lowest relative age probabilities (i.e., the fewest number of grains making up the peak, ~5-7), the Late Triassic – Late Jurassic/Early Cretaceous populations have the next lowest age probabilities, and the Late Cretaceous

– Early/Middle Eocene peaks have the greatest relative age probabilities (i.e., the greatest number of grains making up the peak, ~30-50) (Fig. 2).

Precambrian U-Pb grain-age populations were detected in all samples, and exist in two major groups: 1300 Ma – 1900 Ma, and 2200 Ma – 2900 Ma (Fig. 2). Grain-age populations vary between samples, but samples inboard of CV14-16 generally show a higher proportion of Paleoproterozoic – Archean grains, and samples outboard of (and including) CV14-16 show more Mesoproterozoic – Early Paleoproterozoic grains (Fig. 2).

Maximum depositional ages, calculated based on the weighted average of the youngest three grains in a sample, range from 61 Ma – 51 Ma for the Orca Group in eastern Prince William Sound (Fig. 1).

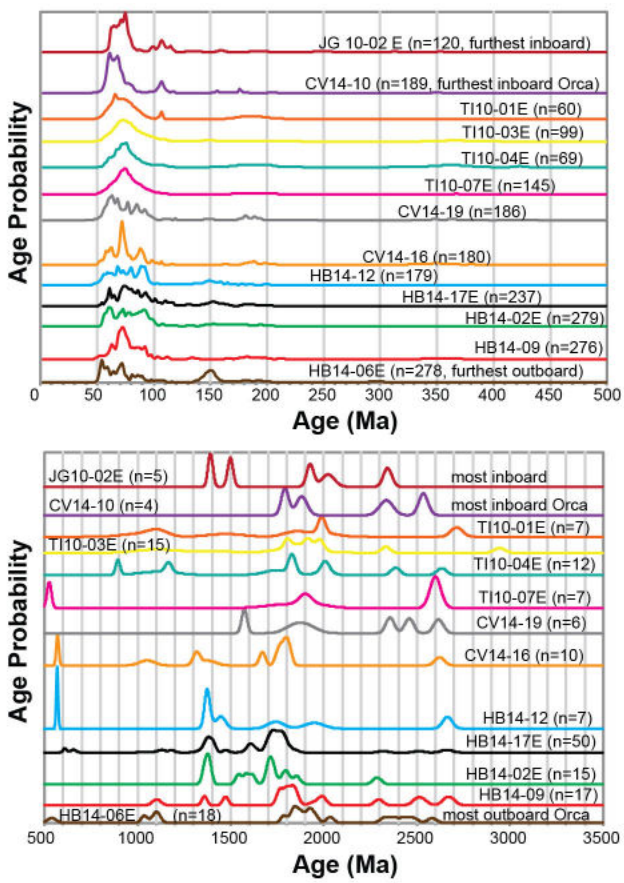

Figure 2. Normalized relative age probability distribution functions, from 0-3500 Ma, for the Orca Group of eastern Prince William Sound. Note the scale change on the x-axis at 500 Ma. Plots generated using Excel Normalized Prob Plot program from the Arizona LaserChron Center at the University of Arizona. "E" designates samples that were enhanced for Precambrian grains.

DISCUSSION

The Orca Group in Prince William Sound

Early work divided the Orca Group in western Prince William Sound (PWS) into three distinct, fault-bounded, geo- and thermo-chronologically distinct belts, based on maximum depositional age (MDA) and zircon fission track (ZFT) thermal history (Fig. 3) (see Hilbert-Wolf, 2012; Carlson, 2012). The most inboard Paleocene belt was deposited before 57 to 60 Ma, and it has significant ZFT cooling ages between 49 – 53 Ma and between 37 – 40 Ma, which are probably related to heating events associated with the 61 – 50 Ma Sanak-Baranof belt plutonism and the 37-40 Ma Eshamy suite plutonism, respectively (Hilbert-Wolf, 2012; Carlson, 2012). The middle, Early Eocene belt on Evans and Latouche Islands was deposited before 38 Ma, and it has cooling grain-age populations at ~41 Ma and ~30 Ma, which are possibly due heating events related to Eshamy suite plutonism and uplift/exhumation of the Yakutat microplate, respectively (Enkelmann et al., 2010; Hilbert-Wolf, 2012; Carlson, 2012). The most outboard, Late Eocene belt on Montague Island, was deposited before 34 to 35 Ma, and it is distinct because it shows no thermal resetting of zircons since deposition (Hilbert-Wolf, 2012; Carlson, 2012).

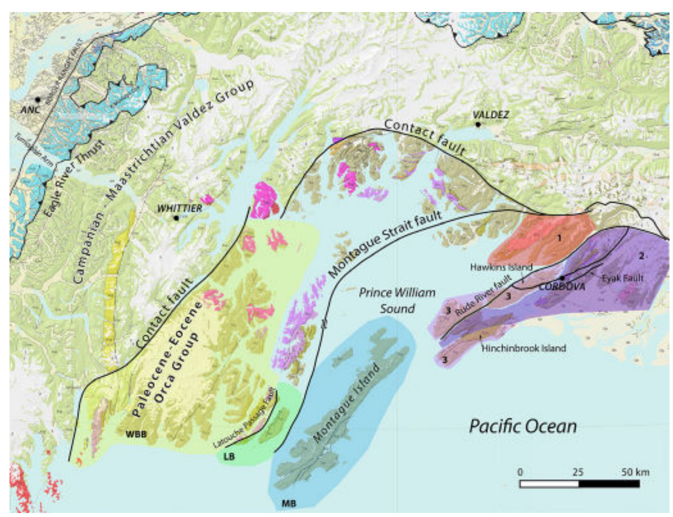

Figure 3. Map of Orca Group belts in Prince William Sound. WBB = Whale Bay/Bainbridge belt; LB = Latouche Belt; MB = Montague Belt (Carlson, 2012; Hilbert-Wolf, 2012). Belts 1, 2, and 3 in eastern Prince William Sound do not correspond to Carlson's (2012) and Hilbert-Wolf's (2012) belts (see also Alejos, this volume). Map modified from Carlson (2012), and base map after Wilson and Hults (2008). See text for discussion of belts.

In eastern Prince William Sound, the range of maximum depositional ages for the Orca Group that we present in this study is 61 Ma – 51 Ma. It is not easy to delineate belts of Orca rocks with faults in eastern Prince William Sound because there appears to be more of a continuum of ages as compared to ages in western PWS. The only obvious groups are Orca rocks that were deposited before the intrusion of the 54.8 ± 0.7 Ma Sheep Bay pluton and the 54.5 ± 1.7 Ma McKinley Peak pluton, and rocks deposited after intrusion (Lempert, this volume). Using ZFT analysis, Izykowski (2011) found a major thermal break across the Rude River fault in eastern Prince William Sound (Fig. 3). All samples show a significant cooling grain-age population at ~49 Ma, which is likely due to the 61 – 50 Ma plutonism of the Sanak-Baranof belt, and samples to the east of the Rude River fault exhibit a consistent population of grain cooling ages at ~31 Ma, which is possibly due to uplift and exhumation of these rocks related to Yakutat collision to the east (Izykowski, 2011). Farther to the southwest along the Rude River fault, it would appear that this prominent discontinuity does not exist and rocks of either side of the fault have a young cooling age between 28 and 35 Ma (Alejos, this volume).

Together, these data show that it is not possible to carry over Hilbert-Wolf's (2012) and Carlson's (2012) belts of Orca Group rocks from western Prince William Sound to eastern Prince William Sound based on maximum depositional ages and thermal histories. Orca Group rocks in the west (Montague) have a maximum depositional age range of 34 Ma, inboard belts record combinations of three distinct thermal events since deposition, and the most outboard Montague belt has not been affected by any significant thermal events since deposition (Carlson, 2012; Hilbert-Wolf, 2012). Conversely, Orca rocks in eastern Prince William Sound have an MDA range of 10 Ma and record a combination of only two thermal events since deposition (Izykowski, 2011; Alejos, this volume). Thus we suggest that Orca rocks in eastern Prince William Sound constitute three new belts of material: 1) a pre-55 Ma belt, which was deposited before the intrusion of the 54.8 ± 0.7 Ma Sheep Bay pluton and the 54.5 ± 1.7 Ma McKinley peak pluton and shows thermal effects at ~50 Ma, 2) a pre-55 Ma belt that felt cooling effects at ~30 Ma, and 3) a post-55 Ma belt that felt cooling effects at ~30 Ma (Fig. 3.)

Despite the slight differences in maximum depositional age ranges between the Orca Group of western Prince William Sound and eastern Prince William Sound, the overall grain-age spectra for the east and west are strikingly similar (Fig. 4). This result suggests that the entire Orca Group in Prince William Sound was derived from the same region.

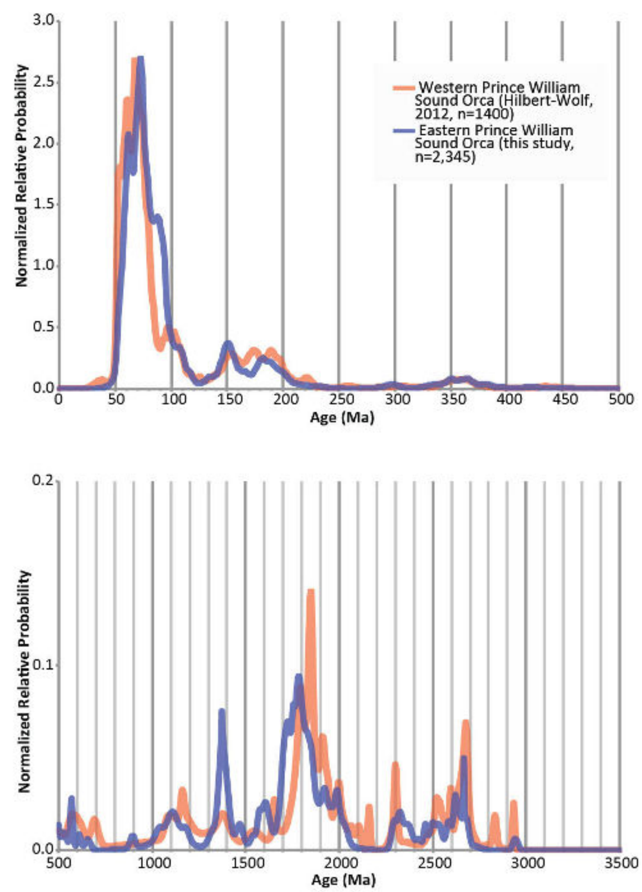

Figure 4. Normalized relative age probability distribution functions, from 0-3500 Ma, of the Orca Group in western Prince William Sound and eastern Prince William Sound (Hilbert-Wolf, 2012; this study). Phanerozoic and Precambrian grain-age populations are strikingly similar, which suggests that the entire Orca Group in Prince William Sound is sourced by the same region. Note the scale change in the x and y axes at 500 Ma. For ease of viewing, kernel, which deals with error, is 1 in the eastern Precambrian spectrum (more error incorporated) and 2 in the western spectrum (less error incorporated).

Provenance of Chugach-Prince William terrane

U-Pb detrital zircon data for the Orca Group in eastern Prince William Sound reinforce along-strike correlations and similarities of different units in the CPW terrane. Inferred correlative units to the Orca Group include the most outboard Sitka Greywacke on Baranof Island and the Sitkalidak Formation on Kodiak Island (Rick, 2014; Haeussler et al., 2006; Roig, 2014; Olivas, 2012; Frett, 2014; Pettiette, 2013; Hilbert-Wolf, 2012; this study). Units interpreted to be correlative with the Valdez Group include the Yakutat Formation, the middle belt of Sitka Greywacke on Baranof Island, the Kodiak and Ghost Rocks formations on Kodiak Island, and the Shumagin Formation on Nagai Island (Haeussler et al., 2006; Rick, 2014; Roig (2014); Olivas, 2012; Roe, 2013; Frett, 2014; Bradley et al., 2009; Kochelek et al., 2011; Amato and Pavlis, 2010; Amato et al., 2013; and Pettiette, 2013). Phanerozoic grain-age populations from the CPW are consistent with U-Pb crystallization ages of plutons and modeled magmatic flare-up periods of the central and northern Coast Mountains Batholith (Gehrels et al., 2009). These results, in combination with other data like Nd, Pb, and Sr data of Farmer et al. (1993), support the hypothesis that the CPW terrane is the missing accretionary wedge for the Coast Mountains Batholith (cf. Roberts, 2013).

Northern Laurentian terranes are dominated by Archean – Paleoproterozoic crustal ages (> 2.5 Ga – 1.9 Ga), while southern Laurentian provinces have mainly Paleoproterozoic – Neoproterozoic ages (1.8 – 1.0 Ga) (Whitmeyer and Karlstrom, 2007). Orca Group correlative units along strike show northern Laurentian zircon ages, but they also show southern Laurentian ages as distinctive as the Grenville orogeny, ~1.3-1.0 Ga. Valdez Group correlative units also show both northern and southern-Laurentian zircon ages, but the Yakutat microplate is distinctly different (Garver and Davidson, in press). Yakutat Precambrian grains show an almost exclusively southern Laurentian signature, including a strong Yavapai-Mazatzal signature. Previous workers have championed the hypothesis that the Yakutat is a displaced unit of the southern CPW terrane, based on reasons such as coeval maximum depositional ages and lithologic similarities (e.g., Rick, 2014; Roberts, 2013; and Cowan, 2003). Our Precambrian U-Pb detrital zircon data support this hypothesis, and they support the restoration of the Chugach-Prince William terrane to a position south of its present location during the time of deposition, which implies subsequent coast parallel-displacement (e.g., Cowan, 2003) (Fig. 5.)

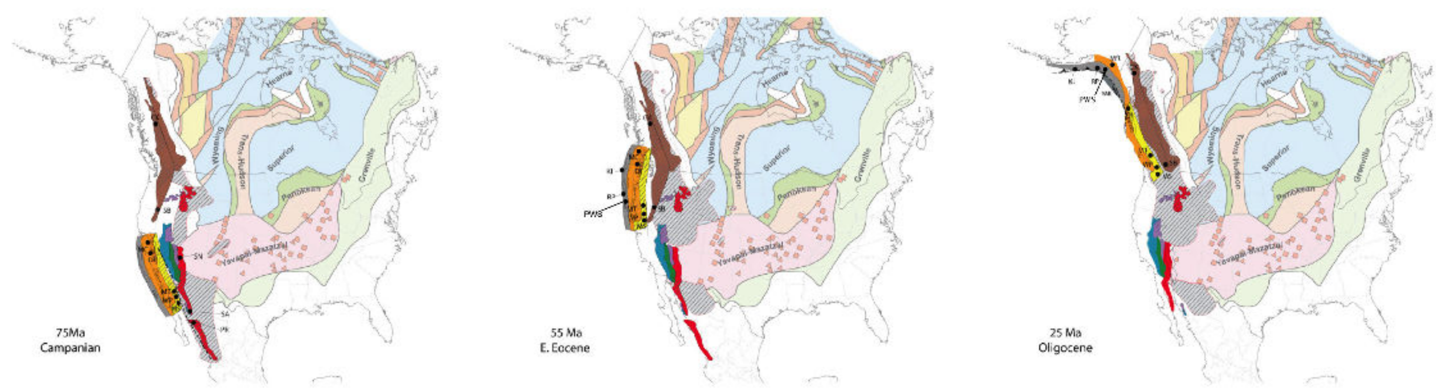

Figure 5. Time-slice reconstructions of possible locations of the Chugach-Prince William terrane (dark grey) and other elements of the North American Cordillera, showing dextral coast-parallel transport. Orange is the Insular superterrane, and yellow is the Coast Mountains batholith. Base map modified from and Piercey and Colpron (2009), and selected elements of the Cordillera and paleomagnetic data locations (letter abbreviations) are from Cowan et al. (1997) and Miller et al. (2006). Reconstructions are faithful to paleomagnetic data from Bol et al. (1992) for the Resurrection Peninsula (RP) and leaf margin analysis of Miller et al. (2006). KI, PWS, and YAK are approximate locations of Knight Island, Prince William Sound, and the Yakutat microplate, respectively. This model places the Chugach-Prince William terrane near the northern Laurentia-southern Laurentia border during deposition (i.e., near the northern border of the Yavapai-Mazatzal terrane), and it implies that the Chugach-Prince William terrane is the missing accretionary wedge of the Coast Mountains batholith.

CONCLUSIONS

New U-Pb detrital zircon data from the Orca Group in eastern Prince William Sound, Alaska, shows that maximum depositional ages of these rocks generally young inboard to outboard, but no obvious age gaps are delineated by mapped faults. Based on this data and zircon fission track data (Alejos, this volume), we suggest that fault-bounded belts of Orca Group rocks proposed by Hilbert-Wolf (2012) and Carlson (2012) in western Prince William Sound do not continue in a simple way into eastern Prince William Sound. Precambrian zircon grains indicate a mixed southern-northern Laurentian source for the Orca Group. These data, in combination with other U-Pb data from the Chugach-Prince William terrane, supports the restoration of the Chugach-Prince William terrane to a location south of its present latitude during the Late Cretaceous – Paleocene (e.g., Cowan, 2003).

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