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AGE AND PROVENANCE OF THE UPPER CRETACEOUS TO PALEOCENE VALDEZ GROUP OF THE CHUGACH TERRANE FROM THE RICHARDSON HIGHWAY AND NORTHERN PRINCE WILLIAM SOUND, ALASKA

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INTRODUCTION

The age and provenance of the southern Alaskan Campanian to Paleocene Valdez Group of the Chugach terrane and its relationship with the younger outboard Paleocene to Eocene Orca Group of the Prince William terrane is poorly understood but an important component of the Cordilleran collage (Plafker et al., 1994). The Valdez and Orca Groups are both part of the Chugach-Prince William terrane (CPW), which is a thick accretionary complex that extends 2200 km along the southern Alaskan margin (Fig. 1; Cowan, 2003). The deep-water turbidites of these terranes are quartzofeldspathic and volcanic-lithic sandstones and basaltic rocks (Dumoulin, 1987; Plafker et al., 1994). The CPW is intruded by near-trench plutons of the Sanak-Baranof belt (Davidson and Garver, 2017) and are believed to be related to a slab window that formed during subduction of Kula-Farallon or Kula-Resurrection spreading ridges (Marshak and Karig, 1977; Delong et al., 1978; Moore et al., 1983; Kusky et al., 1997a; Bradley et al., 2003; Haeussler et al., 2003). There are two hypotheses for the formation of the CPW along the North American Cordilleran margin: 1) either the CPW terrane formed in situ by subduction of the Resurrection plate (Haeussler et al. 2003); or 2) the rocks formed in the Pacific Northwest or California and were transported at least 2000 km along coastwise strike-slip fault systems (Cowan, 2003; Garver and Davidson, 2015).

This study is an investigation into the age and provenance of the Valdez Group and its relationship with the Orca Group in the central Chugach Mountains using detrital zircon U-Pb dates. New detrital zircon U-Pb dates and their grain-age distributions from the Valdez and Orca Group turbidites are combined with dates from Kochelek et al. (2011), Amato et al. (2013), and Davidson and Garver (2017) and then synthesized to understand the difference in age between the units and provenance. New and existing U-Pb dates indicate maximum depositional ages (MDA) of the Valdez Group are concentrated in three groups: 84-78 Ma, 74-65 Ma, and 62-60 Ma. The youngest group of MDAs are age-correlative with the Orca Group but were collected from rocks in areas mapped as Valdez Group, indicating that either Orca Group rocks occur in the Valdez Group or the youngest Valdez Group rocks are stratigraphically equivalent to those of the oldest Orca Group. If the latter, the Valdez Group is not Campanian to Maastrichtian in age as has been traditionally viewed (Plafker et al., 1994) but is Upper Cretaceous to Paleocene and in part correlative to the lowest part of the Orca Group.

GEOLOGIC SETTING

Chugach terrane

The Chugach terrane is composed of 1) Late Triassic to Jurassic glaucophane greenschist with local blueschist facies as young as Early Cretaceous (Day et al., 2016), 2) the Early Triassic to Early Cretaceous McHugh Complex, and 3) the Late Cretaceous Valdez Group (Plafker et al., 1994; Amato et al., 2013). The McHugh Complex is divided into two assemblages based on distinctive lithologies and MDAs: the 101-91 Ma McHugh Creek assemblage consisting of massive

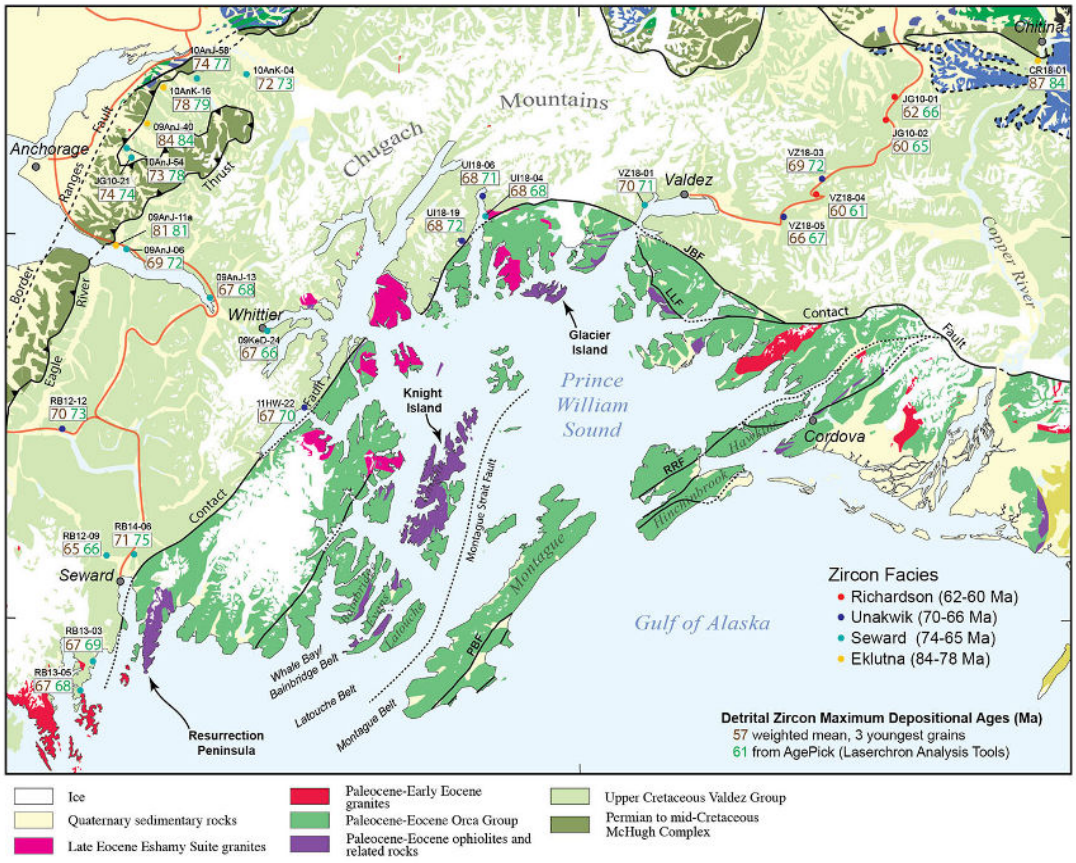

Figure 1. Geologic map of Prince William Sound, Alaska (modified from Bradley and Miller, 2006).

sandstones and conglomerates, and the 169-156 Ma Potter Creek assemblage consisting of chert, argillite, and volcanic rocks (Amato and Pavlis, 2010; Amato et al., 2013). The age of the Valdez Group has been previously constrained by sparse Inoceramus fossils from Turnagain Arm near Anchorage, indicating that the Valdez Group is no older than Late Cretaceous in age (Moffit, 1954). The Coast Mountains in British Columbia are inferred to be the primary source of the flysch (Plafker et al., 1994; Haeussler et al., 2006).

Prince William terrane

The Prince William (PW) terrane is composed of the Paleocene to Eocene Orca Group (Dumoulin, 1987; Plafker et al., 1994; Garver and Davidson, 2015). The Orca Group has a more diverse lithology than the Valdez Group with abundant volcanic rocks including breccias, sills, dikes, and pillows, all with a basaltic composition, and these rocks have experienced a lesser degree of metamorphism (Plafker and MacNiel, 1966).

Border Ranges Fault System

The Border Ranges fault (BRF) system is the tectonic boundary between the Chugach terrane and the inboard units of the Wrangellia composite terrane (MacKevett and Plafker, 1974; Pavlis, 1982; Pavlis et al., 1988, 2003; Pavlis and Crouse, 1989; Plafker et al., 1989, 1994; Cowan, 2003; Roeske et al., 2003; Pavlis and Roeske, 2007). If there has been coastwise translation of the CPW, it most likely was accommodated on the BRF (Cowan, 2003). The BRF system is responsible for underthrusting the Chugach terrane a horizontal distance of at least 40 km beneath the Wrangellia composite terrane (Plafker et al., 1994).

Contact Fault

Current mapping separates the older Valdez Group of the Chugach terrane from the younger Orca Group of the Prince William terrane along the Contact fault system (Bol and Roeske, 1993; Plakfer et al., 1994; Wilson et al., 2015). The Contact fault is a strike-slip and dip-slip fault between the Chugach and Prince

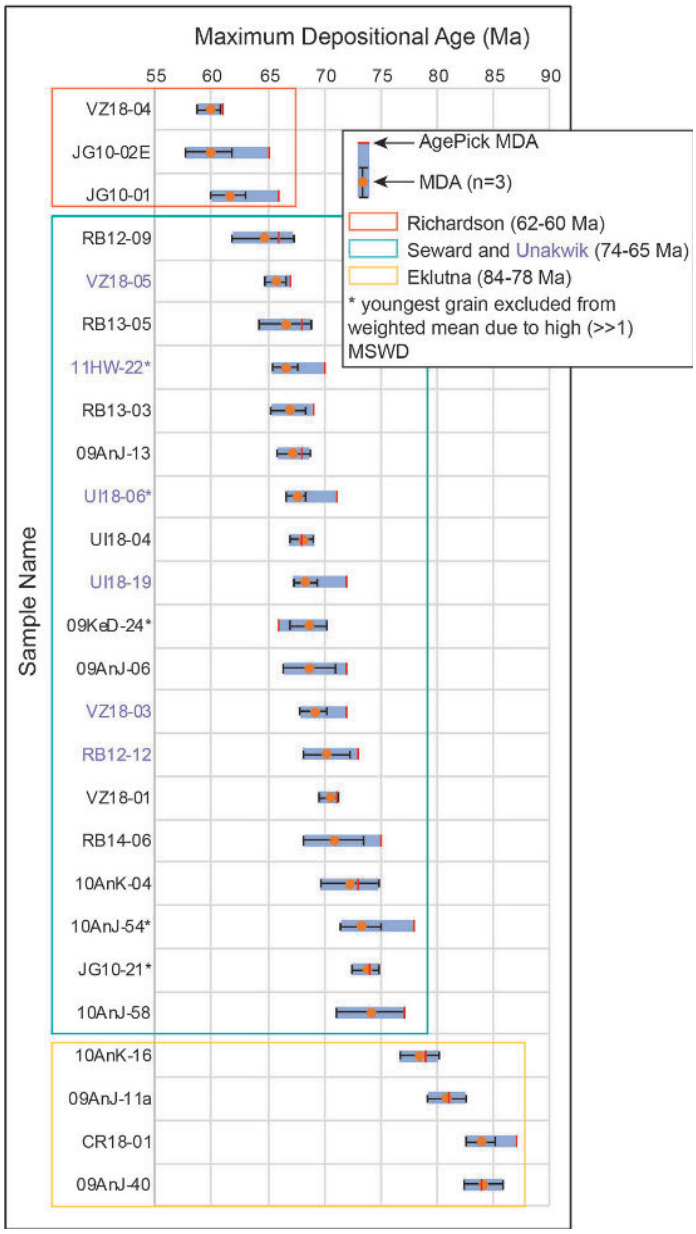

Figure 2. Maximum depositional ages (MDAs) of Valdez Group turbidites in Prince William Sound. MDA (n=3) is the weighted mean of the three youngest coherent zircons from a sample, and AgePick MDA was determined using the AgePick macro of Gehrels (2012). Blue bars show the range of uncertainty of the MDA for a sample.

William terranes and is locally called the Jack Bay fault in northern Prince William Sound. Bol and Roeske (1993) proposes the Contact fault is a strike-slip fault between the terranes, while Plafker et al. (1994) believes the Contact fault places the Orca Group underneath the Valdez Group. Malik et al. (2019), however, suggests the Contact fault may not actually be a terrane bounding fault. The Contact fault cuts rocks in an east-west arc through Valdez Arm and

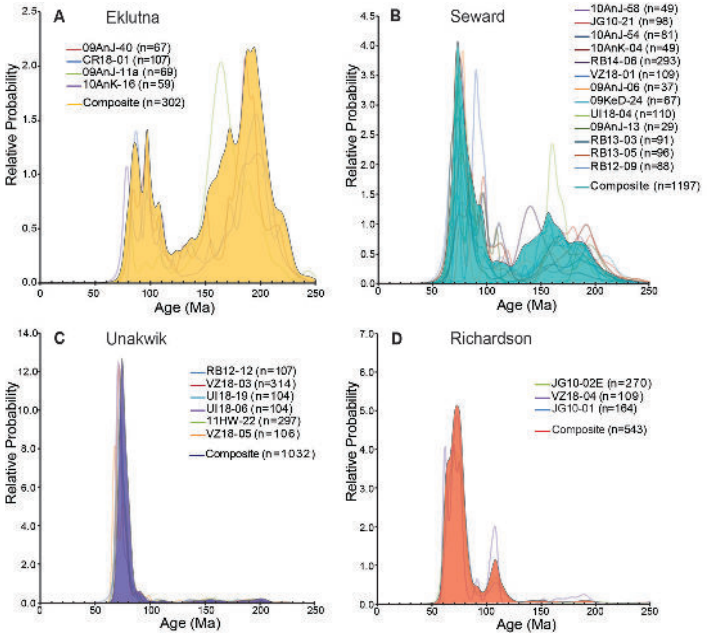

Figure 3. Probability density functions (PDFs) of detrital zircon U/Pb ages for the four zircon facies identified in the Valdez Group. Filled PDFs are composites of all samples in a facies. Legends are organized from oldest to youngest MDA in the group. (A) Eklutna facies with MDAs between 84-78 Ma, (B) Seward facies with MDAs between 74-65 Ma, (C) Unakwik facies with MDAs between 70-66 Ma, and (D) Richardson facies with MDAs between 62-60 Ma.

Unakwik Inlet in our study area.

METHODS

U-Pb ages of detrital zircons were determined from ten sandstone samples of the Valdez Group from northern Prince William Sound and the Richardson Highway as part of this project. For this study, zircon crystals were extracted from our samples with standard methods of crushing, grinding, Rogers Table, heavy liquids, and Frantz magnetic separation. Polished detrital zircons were then dated by U-Pb technique at the Arizona LaserChron Center with laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) using standard methods to determine their age and provenance. Zircons were randomly chosen for analysis of 100 or 300 grains per sample.

RESULTS

U-Pb data were collected from a total of 1,063 zircon grains from eight sandstone samples of the Valdez Group from near Chitina, along the Richardson Highway, and northern Prince William Sound. Our

project contributes to a total of 3,074 grains dated (26 samples) from the Valdez Group. We exclude some published ages of the Valdez Group from Bradley et al. (2009), Kochelek et al. (2011), and Amato et al. (2013) due to poor precision (high 1σ error and high MSWD) and a low number of zircons analyzed.

Valdez Group samples are dominated by Early to Late Jurassic, Early to Late Cretaceous, and Paleocene populations with their MDAs ranging from 84.1 to 59.8 Ma. We divide the range of MDAs into three different primary groups by reason of age breaks in the MDAs: 84-78 Ma, 74-65 Ma, and 62-60 Ma (Fig. 2). Each group of samples share similar grain-age distributions and is supported by the Kolmogorov-Smirnoff (K-S) test where the p-value between samples in the group is greater than 0.05 which corresponds to 95% confidence that the samples are not statistically different (Gehrels, 2012). Some samples fail the K-S test but are still considered part of a group because of similarities in grain-age distribution and MDA.

The oldest group, the Eklutna facies, includes previously published samples from Mount Magnificent, Turnagain Arm, and Eklutna River near

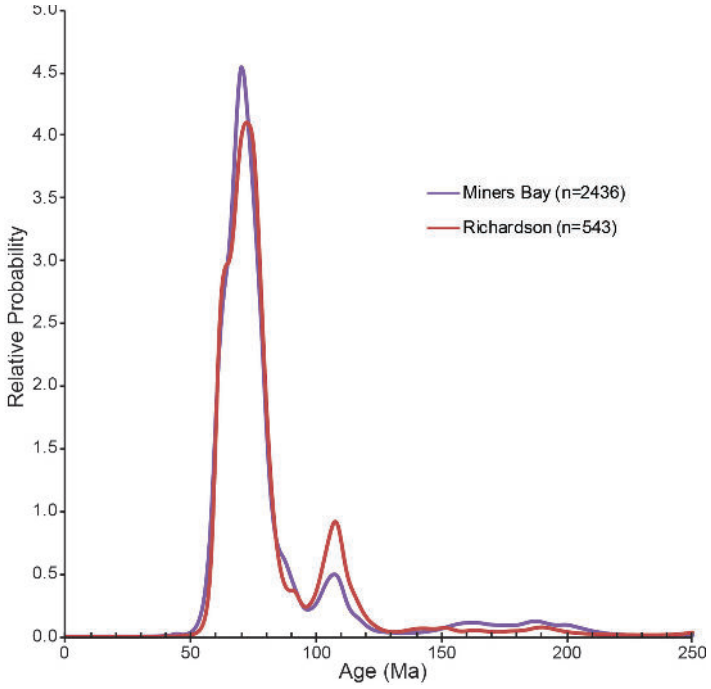

Figure 4. Composite probability density functions of the Richardson facies of the Valdez Group and Miners Bay facies of the Orca Group.

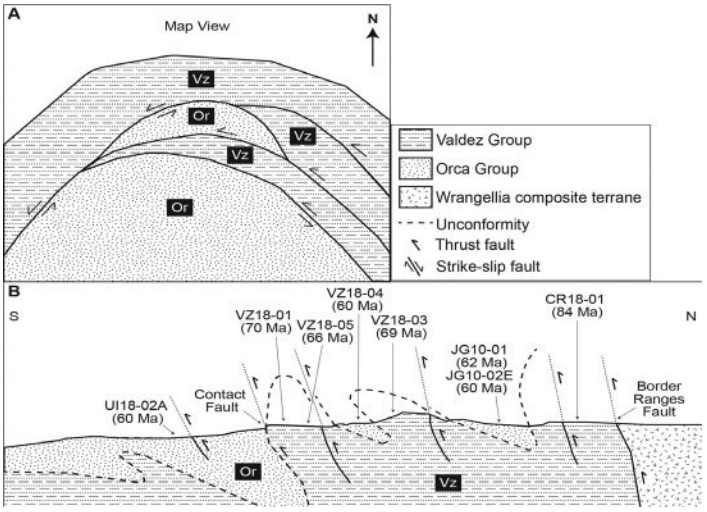

Figure 5. Two possible structural explanations for the occurrence of the young Richardson facies in the Valdez Group. A) The Paleocene rocks are correlative to the Orca Group and occur in the Valdez Group as structural slices. B) The Paleocene rocks were unconformably deposited on top of the Valdez and subsequently folded into the Valdez Group.

Anchorage and one from our study along the Copper River near Chitina (Fig. 1). These four samples (09AnJ-11a, 09AnJ-40, 10AnK-16, and CR18-01) have similar Late Cretaceous populations between 97 and 79 Ma and Early to Middle Jurassic populations between 197 and 164 Ma (Fig. 3A) with MDAs between 84-78 Ma. All samples share Precambrian detrital zircon grains with peaks at ~1465 Ma, ~1800 Ma, ~1980 Ma, and ~2705 Ma. All samples in this group pass the K-S test.

The middle group is the largest and includes nineteen samples: 09AnJ-06, 09AnJ-13, 09KeD-24, 10AnJ-54, 10AnJ-58, 10AnK-04, 11HW-22, JG10-21, RB12-09, RB12-12, RB13-03, RB13-05, RB14-06, UI18-04, UI18-06, UI18-19, VZ18-01, VZ18-03, and VZ18-05 (Fig. 1). The middle group is split into two sub-groups based on grain-age distribution. One sub-group, the Seward facies, has thirteen samples that have pronounced Early to Late Jurassic and Early Cretaceous populations between 192 and 140 Ma with MDAs between 74-65 Ma (Fig. 3B). This sub-group's Precambrian grains have a wide range of ages between ~560 to ~2760 Ma. The other sub-group, the Unakwik facies, includes six samples: 11HW-22, RB12-12, UI18-06, UI18-19, VZ18-03, and VZ18-05 (Fig. 3C). The Unakwik facies, with MDAs between 70-66 Ma, is remarkably uniform and is dominated by Late Cretaceous zircons between 76-68 Ma and do not

have older populations like the Seward facies. These samples share many Precambrian peaks between ~1730 to ~2310 Ma and between ~2550 to ~2740 Ma. VZ18-05 is the only sample in the sub-group that fails the K-S test.

The youngest group, the Richardson facies, includes three samples (JG10-01, JG10-02E, and VZ18-04) collected from rocks mapped as the Valdez Group along the Richardson Highway (Fig. 1) and are dominated by zircons with Late Cretaceous (72-70 Ma) and Early Cretaceous (109-106 Ma) peak ages (Fig. 3D) with MDAs between 62-60 Ma. The samples in this group also have a wide age range of Precambrian grains, but they all share peaks between ~1775 to ~2050 Ma. VZ18-04 fails the K-S test for this group, probably because of the large Cretaceous peak at 108 Ma (Fig. 3D).

DISCUSSION

Grain-age distributions of the Valdez Group are dominated by Paleocene and Cretaceous peaks, possibly originating from an active and partially dissected Late Cretaceous to Paleocene volcanic arc (Garver and Davidson, 2015). Many samples also have Jurassic populations which may come from meta-plutonic basement rocks built on the volcanic arc (Garver and Davidson, 2015). The grain-age distribution of the CPW terrane is strikingly similar to that of the Coast Mountains Batholith Complex (CMB) in British Columbia (Haeussler et al., 2006; Garver and Davidson, 2015), suggesting that the CPW terrane may have formed farther south and adjacent to the CMB (Garver and Davidson, 2015).

The MDAs of the Eklutna facies (84-78 Ma), Seward facies (74-65 Ma) and Unakwik facies (70-66 Ma) suggest that these rocks were deposited in the Cretaceous and are consistent with previous age estimates (Plafker et al., 1994). However, the Richardson facies (62-60 Ma) is Paleocene in age and is age-correlative with the Orca Group. A comparison of the Richardson facies of the Valdez Group with the Miners Bay facies (which includes the three samples that comprise the Richardson facies) of the Orca Group (Fisher, 2019) shows that these rocks are nearly identical (Figs. 1&4). A key question is the stratigraphic alliance of this young facies (62-60 Ma) in the Valdez Group. Samples from the Richardson facies were collected 50 to 100 km away from the Contact fault and along Richardson Highway, an area long-mapped as Valdez Group (Fig. 1). We have two options for the occurrence of Orca Group age-correlative samples in areas mapped as the Valdez Group: 1) the Richardson facies is part of the Valdez Group and is stratigraphically equivalent to the oldest Orca Group (Miners Bay facies); or 2) the Richardson facies is part of the Orca Group and occurs in the Valdez Group as structural slices (Fig. 5A) or was deposited unconformably on top of the Valdez and subsequently folded into the Valdez Group (Fig. 5B).

CONCLUSIONS

Detrital zircon U-Pb ages from turbidites of the Valdez Group of the Chugach terrane in Prince William Sound demonstrate the complex relationship between the Valdez Group with the outboard turbidites of the Paleocene-Eocene Orca Group. New detrital zircon U-Pb data, however, suggests that the Valdez Group is Upper Cretaceous to Paleocene in age. MDAs of the Valdez Group form three groups: 84-78 Ma, 74-65 Ma and 62-60 Ma. The youngest MDA group, the Richardson facies, overlaps in age with the Miners Bay facies from the Orca Group (Fisher et al., 2019). This study supports the conclusions of Malik et al. (2019) that the Contact fault system may not be a terrane boundary (Malik et al., 2019).

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