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TECTONIC EVOLUTION OF THE FLYSCH OF THE CHUGACH TERRANE ON BARANOF ISLAND, ALASKA*:*
Faculty: *JOHN GARVER*, Union College, *CAMERON DAVIDSON*, Carleton College
Students: *BRIAN FRETT*, Carleton College, *KATE KAMINSKI*, Union College, *BRIANNA RICK*, Carleton College, *MEGHAN RIEHL*, Union College, *CLAUDIA ROIG*, Univ. of Puerto Rico, Mayagüez Campus, *ADRIAN WACKETT*, Trinity University,

EVALUATING EXTREME WEATHER RESPONSE IN CONNECTICUT RIVER FLOODPLAIN ENVIRONMENT*:*
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A GEOBIOLOGICAL APPROACH TO UNDERSTANDING DOLOMITE FORMATION AT DEEP SPRINGS LAKE, CA
Faculty: *DAVID JONES*, Amherst College, *JASON TOR*, Hampshire College,
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POTENTIAL EFFECTS OF WATER-LEVEL CHANGES ON ON ISLAND ECOSYSTEMS: A GIS SPATIOTEMPORAL ANALYSIS OF SHORELINE CONFIGURATION
Faculty**:** *KIM DIVER*, Wesleyan Univ.
Students: *RYAN EDGLEY*, California State Polytecnical University-Pomona, *EMILIE SINKLER*, Wesleyan University

PĀHOEHOE LAVA ON MARS AND THE EARTH: A COMPARATIVE STUDY OF INFLATED AND DISRUPTED FLOWS
Faculty: *ANDREW DE WET*, Franklin & Marshall College, *CHRIS HAMILTON*. Univ. Maryland, *JACOB BLEACHER*, NASA, GSFC, *BRENT GARRY*, NASA-GSFC
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THE GEOMORPHIC FOOTPRINT OF MEGATHRUST EARTHQUAKES: A FIELD INVESTIGATION OF CONVERGENT MARGIN MORPHOTECTONICS, NICOYA PENINSULA, COSTA RICA
Faculty*:* *JEFF MARSHALL*, Cal Poly Pomona, *TOM GARDNER*, Trinity University, *MARINO PROTTI, OVSICORI-UNA, SHAWN MORRISH*, Cal Poly Pomona
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HOLOCENE AND MODERN CLIMATE CHANGE IN THE HIGH ARCTIC, SVALBARD NORWAY
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Keck Geology Consortium: Projects 2013-2014
Short Contributions— Chugach Terrane, Alaska Project

STUDIES IN RESURRECTION BAY AND BARANOF ISLAND AIMED AT UNDERSTANDING THE TECTONIC EVOLUTION OF THE CHUGACH-PRINCE WILLIAM TERRANE, ALASKA
Faculty: JOHN I. GARVER, Union College
CAMERON DAVIDSON, Carleton College

DETRITAL ZIRCON U/PB AGES OF THE PALEOCENE ORCA GROUP AND UPPER CRETACEOUS VALDEZ GROUP, RESURRECTION BAY, ALASKA
BRIAN K. FRETT, Carleton College
Research Advisor: Cameron Davidson

EXHUMATION OF THE BARANOF SCHIST, ALASKA DETERMINED THROUGH DETRITAL ZIRCON FISSION TRACK DATING
KATE KAMINSKI, Union College
Research Advisor: John I. Garver

U/PB DATING OF DETRITAL ZIRCONS, BARANOF ISLAND, SE ALASKA
BRIANNA J. RICK, Carleton College
Research Advisor: Cameron Davidson, [John Garver, Union College]

THERMAL EVOLUTION OF THE SITKA GRAYWACKE, BARANOF ISLAND, ALASKA, REVEALED THROUGH ZIRCON FISSION TRACK DATING
MEGHAN PAIGE RIEHL, Union College
Research Advisor: John I. Garver

OXYGEN AND HAFNIUM ISOTOPE GEOCHEMISTRY OF ZIRCON, QUARTZ, AND GARNET FROM THE CRAWFISH INLET AND KRESTOF PLUTONS, BARANOF ISLAND, ALASKA
CLAUDIA I. ROIG, University of Puerto Rico, Mayagüez Campus
Research Advisor: Dr. Aaron J. Cavosie

PETROGRAPHY AND GEOCHEMISTRY OF THE CRAWFISH INLET AND KRESTOF ISLAND PLUTONS, BARANOF ISLAND, ALASKA
ADRIAN A. WACKETT, Trinity University
Research Advisor: Diane R. Smith

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JOHN I. GARVER, Union College
CAMERON DAVIDSON, Carleton College

INTRODUCTION

The Chugach-Prince William (CPW) terrane in southern and southeast Alaska is mainly composed of thick imbricated flysch (most are Maastrichtian to Paleocene) intruded by diachronous near-trench plutons of the Sanak-Baranof belt (Paleocene to Eocene). The sequence is interpreted to represent a thick accretionary complex where turbidites from an adjacent arc and metaplutonuc basement were deposited, accreted, buried, and then intruded by plutons over a short period of time. Our research team has been focused on scientific problems that surround the provenance and age of the flysch (Frett, this volume; Rick, this volume), the burial, metamorphic, and cooling history (Kaminski this volume; Riehl this volume), and the nature of near-trench plutons (Roig, this volume; Wackett, this volume).

The flysch is thick and compositionally uniform, and volume estimates of several million km^3 suggest that it was fed by a single evolving deeply exhumed source terrain (Plafker et al., 1994). All sandstones in the belt are dominated by detrital zircons that are close to the age of deposition, and hence it is clear that that source region supported an active and long-lived Late Cretaceous to Paleocene volcanic arc (Roberts et al., 2013). The metaplutonic basement that supported this arc is mainly made of rocks that produce Mesozoic zircon (mainly Jurassic), with a minor fraction of Paleozoic (mainly Devonian) and Precambrian grains. Our work builds on a number of previous studies that suggests the most likely candidate source is the Coast Mountains Orogen, which currently represents the spine of the BC Coast Range (Plafker et al., 1994; Sample and Reid, 2003). Thus a small amount of translation is required to restore it to be adjacent to its likely source (Cowan, 2003).

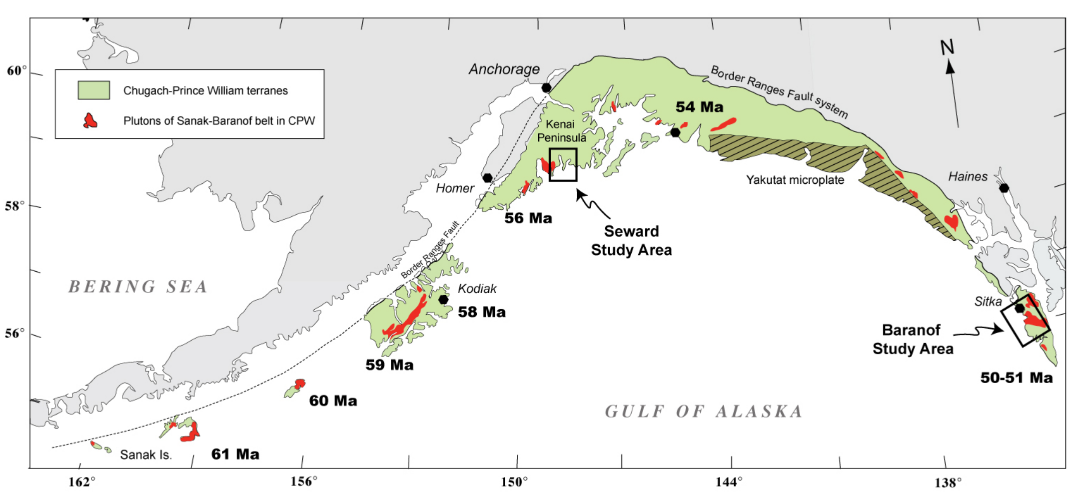

Figure 1. Extent of the Chugach-Prince William terrane in south central Alaska. 2013 field areas are indicated by black boxes. Pluton locations and dates are from Farris and Patterson (2009) and Bradley et al. (2003). Map modified from Pavlis and Roeske (2007).

The Sanak-Baranof belt (SBB) is a series of mainly granodiorite plutons that intrude the CPW along the 2000 km long belt (Bradley et al., 2003). The oldest plutons are in the west (61-62 Ma on Sanak and the Shumagin Islands) and the youngest plutons are in the east (47-53 Ma on Baranof Island). It has long been inferred that these plutons represent near-trench intrusions related to slab window effects caused by ridge-trench interaction. It has been assumed in the literature that the adjacent ridge that drove this plutonism was a major plate boundary in the Pacific, and it was either the Pacific-Kula or the Pacific-Resurrection ridge (cf. Cowan, 2003; Haeussler et al., 2003). The latter boundary requires consideration of a new oceanic plate in the NE pacific, which is not represented by marine magnetic anomalies and would have been wholly subducted by now (i.e. Haeussler et al., 2003).

Slabs of ocean crust that occur as large tectonic slices in the CPW may represent pieces of this offshore ridge. Near Seward Alaska (close to the center of the belt), the CPW terrane has two large ophiolite complexes, the Resurrection Peninsula and Knight Island ophiolites, which have been structurally incorporated into the imbricated flysch. The upper stratigraphy of both ophiolites is distinctive because the pillow basalts are interbedded with clastic sediment that is now thought to be identical to the flysch of the CPW, thus the process that resulted in ophiolite creation must have occurred where turbidites were deposited. The provenance of this interbedded and overlying flysch provides a critical constraint on the age of the ophiolites and the source area that was nearby (see Frett, this volume).

Controversy exists where accretion and intrusion occurred along the North American margin: in one option the accretion and plutonism occurred in the north (Alaska-BC) in relatively close proximity to the present location, and in another option it occurred to the south (BC-WA and all points south) and strike-slip faulting and margin-parallel translation is required to bring these rocks to the north (cf. Cowan, 2003 and Haeussler et al., 2003). However paleomagnetic data from several key localities converge on a solution that requires significant margin-parallel translation of Upper Cretaceous and Paleocene elements of the CPW terrane (see Housen and Roeske, 2009).

Major issues addressed by detrital zircon U/Pb dating are focused on basic questions of the age of the flysch, continuity of accreted belts in the flysch, and the nature of the source rocks revealed in older zircon. Our recent work shows that the clastic cover to the Resurrection ophiolite in the Seward area is definitively Paleocene (~57-60 Ma or younger) and thus allied with the Orca Group, and not the older Valdez Group. On Baranof Island, new detrital zircon dates indicate that what is traditionally viewed as the Baranof Schist appears to be largely Paleocene in age, and not Cretaceous (young belt is 64 to 60 Ma or younger) (see Rick et al., 2014; Rick, this volume). These findings have important implications as to the timing of deposition, accretion, and intrusion between ~60 and 50 Ma.

The belt has a distinctive thermal history and almost all rocks of the CPW experienced prehnite-pumpellyite or higher grade metamorphism soon after deposition and accretion. Cooling following this thermal event is mainly about 50 Ma in the western part of the belt, but younger in the east (Riehl, this volume; Kaminski, this volume). This cooling pattern is likely related to strike-slip deformation and local plutonism that affects rocks in Prince William Sound and to the east, but not rocks to the west. ZFT dates from the CPW rocks on Baranof Island are relatively uniform and mainly between 30 and 40 Ma, which may indicate detachment and exhumation as strike-slip faults reworked the outer BC margin in the mid Tertiary (Kaminski, this volume).

The plutons of the Sanak-Baranof belt punctuate the tectonic processes that built the CPW wedge. The easternmost part of the CPW is intruded by the Crawfish Inlet and allied plutons on Baranof Island. New U/Pb dates across the Crawfish pluton, geochemistry, and oxygen isotopes suggest a more protracted history of intrusion (47-53 Ma) that was driven by at least two distinct types of mantle melts mixing with sedimentary material most likely derived from the accretionary wedge (Wackett et al., 2014; Wackett, this volume; Roig, this volume).

The history of the CPW undoubtedly involves margin-parallel translation, but the amount of displacement is controversial. In some scenarios, displacements of 1000 km or less are entertained based mainly on potential geologic ties; however, displacement of nearly 3000 km are required if paleomagnetic data and key geological observations are considered. Hence in our analysis of the CPW and SBB plutons we are focused on building an integrated geologic history along the belt where robust data sets can be used to constrain or refute mutually exclusive hypotheses on the origin and original disposition of these rocks.

RESEARCH

1) Age and Provenance of flysch of the CPW. Central to the research mission of this project is a full understanding of the age and provenance of the flysch of the CPW belt. The belt is thick and essentially unfossiliferous, but the coarse clastic rocks have a rich record of their provenance. Our previous work has focused on correlative rocks in the Shumagins (Roe, 2013), Kodiak (Olivas, 2012), Kenai (Pettiette, 2013), Prince William Sound (Hilbert-Wolf, 2012), and specific detrital zircon studies across the belt (Roberts, 2013).

Bri Rick (Carleton College) investigated the age of detrital zircon from the belt of flysch that is mapped as the Sitka Graywacke. These rocks include the relatively low-grade rocks of the Sitka Graywacke in Sitka Sound that were studied by Haeussler et al., 2004), but most of her effort was on metasediments in Whale Bay that are informally called the Baranof Schist. An important question addressed in this study is the relationship of flysch to the NW of the Crawfish Inlet Pluton to those strata on the SE side of the pluton where they are higher metamorphic grade. With 725 new single U/Pb zircon dates from seven sandstone samples (194 from rocks in Sitka Sound, and 531 from rocks in Whale Bay). Her analysis was able to capitalize on the 492 single zircon dates from seven sandstone samples, already published (Haeussler et al., 2004) and she has been able to demonstrate that there are three belts of rocks with young zircon populations that constrain depositional age to: A) an inboard Albian belt at 105-95 Ma; B) an intermediate Campanian-Maastrichtian Belt at 75-65 Ma; C) an outboard Paleocene belt deposited 65-60 Ma. This young Paleocene belt is remarkable and an outstanding discovery because much previous work in this area has assumed that the Baranof Schist is mid-Cretaceous or older (i.e. Loney et al., 1975), and here she has demonstrated that it is young and thus correlative to the Orca Group in Prince William Sound (see also Rick et al., 2014).

Brian Frett (Carleton College) focused on understanding the age of the clastic cover to the Resurrection Peninsula ophiolite in the Seward area. This work builds on our previous effort (Pettiette, 2013), that demonstrated a Paleocene age for strata that depositionally overlie pillow basalt units of the ophiolite. With 458 new concordant dates on detrital zircon from five new samples, he was able to build on the 402 single grain ages from four samples reported previously (Pettiette, 2103) and expand the known belt of younger Paleocene strata that are inferred to be allied with the ophiolite. A major finding of this work is that the clastic cover to the ophiolite is now known to be quite extensive and it includes all of Fox Island, not just the eastern side as mapped by Kusky and Young (1999). Samples with definitive Cretaceous minimum depositional ages occur on the west side of the Sound. Thus a relatively important structure likely runs in Resurrection Sound, and similar to other well-studied parts of the belt, this structure is an offset of the Contact fault.

2) Thermal history of the Sitka Graywacke and Baranof Schist. Across the CPW belt there is an important thermal history related to post-accretion tectonism and plutonism. Our previous work has focused on more western elements in the belt, including the Shumagin Islands (Deluca, 2013), Kodiak Island (Garver et al. 2010; Deluca, 2013), western Prince William Sound (Carlson, 2012), eastern Prince William Sound (Garver et al., 2011; 2012; Izykowski, 2011; Izykowski et al., 2011; Milde, 2011).

Kate Kaminski (Union College) focused on determining zircon fission track ages from twelve samples (352 single grain ages) taken from a 25 km transect along the Whale Bay on Baranof Island. Rocks along this transect include the Baranof Schist, and the ~50 Ma Crawfish Inlet Pluton. Previous work has established that the primary cooling ages on biotite (K-Ar and Ar-Ar) are mainly 48-43 Ma (closure about 350°C - see data summary in Karl et al., 2014).

The ZFT cooling ages, with a slightly lower closure temperature (~250°C or slightly higher), have ages of 27-37 Ma, indicating that cooling slowed considerably following an initial rapid post-intrusive cooling. The cooling curves for the Baranof Schist and the nearby Chugach Metamorphic Complex (CMC) are similar and both units show rapid cooling (~120ºC/Myr), then after about 5-6 Myr, these rates decreased significantly (~7ºC/Myr). The CMC cooling occurred slightly earlier, but the pattern is the same and therefore may be related to the same tectonic process. The initial cooling pattern is also similar to the slightly younger Leech River Schist (LRC) on Vancouver Island, but these rocks have a slightly different cooling history because the LRC was rapidly brought to the surface by the Oligocene (see also Kaminski et al., 2014).

Meghan Riehl (Union College) focused on zircon fission track dating of seven samples (248 single grain ages) taken from the Sitka Graywacke around Sitka Sound on Baranof Island. This study is on rocks of the type section of the Sitka Graywacke where the metamorphic grade is generally prehnite-pumpellyite to lower greenschist facies and all of the rocks sampled are typical sandstones of the flysch sequence. All samples have zircon fission-track ages that are reset, which indicates that they were heated sufficiently to fully anneal all pre-existing fission tracks (likely >250 to 280°C). ZFT cooling ages from this area are mainly between 29 and 34 Ma and are similar to the cooling ages from the Baranof Schist (above). An important issue is whether this period of cooling is related to erosional exhumation. The sedimentary sequences flanking the Baranof block, the Admiralty trough to the east and Yakutat block to the west, would suggest that erosion was at least partly responsible for exhumation in the Oligocene. Strike-slip faulting may have cause differential block movement in this interval.

3) Intrusive history of the Crawfish Inlet Pluton and allied plutons. After imbrication and accretion, flysch of the CPW was intruded by a suite of diachronous near-trench plutons, most of which belong to the Sanak-Baranof belt (SBB). Our previous work on the age and source of melt for these plutons (Short, 2013) and the geochemistry of volcanic rocks in the CPW (Miner, 2012) has been important in constraining the geotectonic setting at the time of intrusion (see also Davidson et al., 2012; Johnson, 2012).

Adrian Wackett (Trinity University) collected and analyzed 23 samples of host rocks and mafic enclaves for petrography, major and trace elements, and Sr and Nd isotopes to better understand the intrusive history of the Crawfish Inlet pluton and the nearby Krestof pluton. These data combined with new and existing U/Pb dates on the pluton allows for a good understanding of the source of magma and changes in the magma through time. Trace element and REE profiles for the Crawfish and Krestof plutons are similar to the CPW of the accretionary wedge sediments. Crawfish and Krestof samples plot near or within the mantle array on an ε_{Nd} vs. $^{87}Sr/^{86}Sr_{initial}$ diagram. Despite the spatial and temporal proximity of the Crawfish and Krestof intrusions, the least evolved enclaves in these intrusives have trace element and Sr-Nd isotopic characteristics that indicate two distinct mantle sources. Sr and Nd isotopic compositions for both enclaves and host tonalities and granodiorites of the Crawfish and Krestof plutons suggest minimal input from accretionary wedge materials (see also Wackett et al., 2014).

Claudia I. Roig (University of Puerto Rico, Mayagüez) investigated a representative population of igneous zircon, quartz, and garnet from the Krestof and Crawfish Inlet plutons using $\delta^{18}O$ by laser fluorination. She also dated the plutons using U/Pb on zircon, and evaluated Hf isotopes on zircon. U/Pb ages from seven samples within the Crawfish Inlet pluton and one sample from a small satellite sill-like stock range from 47.3±1.2 to 53.1±0.8 Ma. Nine zircon samples lie in the "supracrustal" field, as zircon with $\delta^{18}O$ > 6‰ are not known from uncontaminated mantle-derived magmas. Mineral oxygen fractionations were calculated for quartz, zircon, and garnet pairs and a comparison of $\delta^{18}O$ (zircon) to $\delta^{18}O$ (qtz) suggest equilibrium isotherms of 515° and 630°C - lower than expected for magmatic temperatures, but two samples fall on the 700° C isotherm, which likely reflect original magmatic conditions. The oxygen isotope ratio versus εHf for zircon from Crawfish pluton shows a clear relationship with the more primitive (juvenile) zircons with higher εHf values record the least evolved oxygen isotope ratios. The magmas became more dominated by mantle-derived melts as shown by higher εHf values through the intrusive age of the suite.

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