PROCEEDINGS OF THE TWENTY-SIXTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

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2012-2013 PROJECTS

TECTONIC EVOLUTION OF THE CHUGACH-PRINCE WILLIAM TERRANE: SHUMAGIN ISLANDS AND KENAI PENINSULA, ALASKA
Faculty: *JOHN GARVER*, Union College, *CAMERON DAVIDSON*, Carleton College
Students: *MICHAEL DELUCA*, Union College, *NICOLAS ROBERTS*, Carleton College, *ROSE PETTIETTE*, Washington & Lee University, *ALEXANDER SHORT*, University of Minnesota-Morris, *CARLY ROE*, Lawrence University.

LAVAS AND INTERBEDS OF THE POWDER RIVER VOLCANIC FIELD, NORTHEASTERN OREGON
Faculty: *NICHOLAS BADER & KIRSTEN NICOLAYSEN*, Whitman College.
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BIOGEOCHEMICAL CARBON CYCLING IN FLUVIAL SYSTEMS FROM BIVALVE SHELL GEOCHEMISTRY - USING THE MODERN TO UNDERSTAND THE PAST
Faculty: *DAVID GILLIKIN*, Union College, *DAVID GOODWIN*, Denison University.
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METASOMATISM AND THE TECTONICS OF SANTA CATALINA ISLAND: TESTING NEW AND OLD MODELS
Faculty: *ZEB PAGE*, Oberlin College, *EMILY WALSH*, Cornell College.
Students: *MICHAEL BARTHELMES*, Cornell College, *WILLIAM TOWBIN*, Oberlin College, *ABIGAIL SEYMOUR*, Colorado College, *MITCHELL AWALT*, Macalester College, *FREDY, AGUIRRE*, Franklin & Marshall College, *LAUREN MAGLIOZZI*, Smith College.

GEOLOGY, PALEOECOLOGY AND PALEOCLIMATE OF THE PALEOGENE CHICKALOON FORMATION, MATANUSKA VALLEY, ALASKA
Faculty: *CHRIS WILLIAMS*, Franklin & Marshall College, *DAVID SUNDERLIN*, Lafayette College.
Students: *MOLLY REYNOLDS*, Franklin & Marshall College, *JACLYN WHITE*, Lafayette College, *LORELEI CURTIN*, Pomona College, *TYLER SCHUETZ*, Carleton College, *BRENNAN O'CONNELL*, Colorado College, *SHAWN MOORE*, Smith College.

CRETACEOUS TO MIOCENE EVOLUTION OF THE NORTHERN SNAKE RANGE METAMORPHIC CORE COMPLEX: ASSESSING THE SLIP HISTORY OF THE SNAKE RANGE DECOLLEMENT AND SPATIAL VARIATIONS IN THE TIMING OF FOOTWALL DEFORMATION, METAMORPHISM, AND EXHUMATION
Faculty: *MARTIN WONG*, Colgate University, *PHIL GANS*, University of California-Santa Barbara.
Students: *EVAN MONROE*, University of California-Santa Barbara, *CASEY PORTELA*, Colgate University, *JOSEPH WILCH*, The College of Wooster, *JORY LERBACK*, Franklin & Marshall College, *WILLIAM BENDER*, Whitman College, *JORDAN ELMIGER*, Virginia Polytechnic Institute and State University.

THE ROLE OF GROUNDWATER IN THE FLOODING HISTORY OF CLEAR LAKE, WISCONSIN
Faculty: *SUSAN SWANSON*, Beloit College, *JUSTIN DODD*, Northern Illinois University.
Students: *NICHOLAS ICKS*, Northern Illinois University, *GRACE GRAHAM*, Beloit College, *NOA KARR*, Mt. Holyoke College, *CAROLINE LABRIOLA*, Colgate University, *BARRY CHEW*, California State University-San Bernardino, *LEIGH HONOROF*, Mt. Holyoke College.

PALEOENVIRONMENTAL RECORDS AND EARLY DIAGENESIS OF MARL LAKE SEDIMENTS: A CASE STUDY FROM LOUGH CARRA, WESTERN IRELAND
Faculty: *ANNA MARTINI*, Amherst College, *TIM KU*, Wesleyan University.
Students: *SARAH SHACKLETON*, Wesleyan University, *LAURA HAYNES*, Pomona College, *ALYSSA DONOVAN*, Amherst College.

INTERDISCIPLINARY STUDIES IN THE CRITICAL ZONE, BOULDER CREEK CATCHMENT, FRONT RANGE, COLORADO
Faculty: David Dethier, Williams College, Will Ouimet, U. Connecticut.
Students: CLAUDIA CORONA, Williams College, HANNAH MONDRACH, University of Connecticut, ANNETTE PATTON, Whitman College, BENJAMIN PURINTON, Wesleyan University, TIMOTHY BOATENG, Amherst College, CHRISTOPHER HALCSIK, Beloit College.

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Keck Geology Consortium: Projects 2012-2013
Short Contributions— Matanuska, Alaska Project

GEOLOGY, PALEOECOLOGY AND PALEOCLIMATE OF THE PALEOGENE CHICKALOON FORMATION, MATANUSKA VALLEY, ALASKA
Faculty: *CHRIS WILLIAMS*, Franklin & Marshall College, *DAVID SUNDERLIN*, Lafayette College.

CLIMATE AND PLANT INTERACTIONS IN AN ANCIENT ALASKAN RAINFOREST
MOLLY REYNOLDS, Franklin and Marshall College
Research Advisor: Christopher Williams

GROWTH RING ANALYSIS OF *METASEQUOIA* FROM THE NORTHEAST USA AND THE PALEOCENE/EOCENE CHICKALOON FORMATION, ALASKA
JACLYN WHITE, Lafayette College
Research Advisor: David Sunderlin

ZIRCON U-PB GEOCHRONOLOGY FROM THE PALEOCENE-EOCENE CHICKALOON FORMATION
LORELEI CURTIN, Pomona College
Research Advisor: Robert Gaines

EXAMINING THE PALEOENVIRONMENT OF THE CHICKALOON FORMATION, MATANUSKA VALLEY, ALASKA THROUGH *CAMPELOMA* AND *UNIONOIDA* FOSSIL ASSEMBLAGES
TYLER SCHUETZ, Carleton College
Research Advisor: Clint Cowan

USING STABLE ISOTOPE GEOCHEMISTRY TO RECONSTRUCT THE PALEOHYDROLOGY AND PALEOCLIMATE OF THE PALEOCENE-EOCENE CHICKALOON FORMATION, ALASKA
BRENNAN O'CONNELL, Colorado College
Research Advisor: Henry Fricke

PROVENANCE ANALYSIS OF MEDIAL BASIN CHANNEL SANDS IN THE CHICKALOON FORMATION, MATANUSKA VALLEY, ALASKA
SHAWN A. MOORE, Smith College, Northampton MA
Research Advisor: Bosiljka Glumac

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ZIRCON U-PB GEOCHRONOLOGY FROM THE PALEOCENE-EOCENE CHICKALOON FORMATION

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Research Advisor: Robert Gaines

INTRODUCTION

The Chickaloon Formation, found in the Matanuska forearc basin of south-central Alaska, is an important paleoecological record from the late Paleocene and early Eocene. The Chickaloon contains various fossil leaf assemblages, from which leaf-margin analyses indicate that average temperature was approximately 11–14.5°C (Loope, 2009; Sunderlin et al. 2011), considerably warmer than the current mean annual temperature of 1.5°C in the study area. The Paleocene Eocene Thermal Maximum (PETM) interrupted the steady decline in global temperatures during the Cenozoic with a sudden 5–8°C increase, accompanied by a global negative carbon isotope excursion, which implies a large-scale release of organic carbon into the atmosphere. This event is often used as an analogue to impending anthropogenic climate change, but it is poorly documented at northern high latitudes. Thus, the Chickaloon provides an opportunity to better understand the effect of elevated global temperatures on high-latitude climate and ecosystems.

Within the Chickaloon Formation are conformable rock types called tonsteins, which are a specific type of airfall tuff that form when air-borne pyroclastic material falls into a peat-forming, organic-rich environment, and are preserved in the sedimentary record as laterally continuous kaolinite-rich mudstone beds within coal seams. They are useful for correlating coal seams, and may contain trace elements that are potential indicators for alkali ore deposits (Dai et al., 2011). In this study, zircons from five tonsteins were U-Pb dated by LA-ICP-MS in order to provide a better framework for the Chickaloon Formation stratigraphy and precisely and accurately determine the timing of deposition of the leaf fossil-rich beds and their relationship to the PETM.

GEOLOGIC SETTING

The Matanuska Valley is bounded on the northern side by the Talkeetna Mountains volcanic arc, which is comprised of Jurassic calc-alkaline lava flows, tuff, and volcaniclastics (Trop et al., 2003). The southern side of the basin is adjacent to the Chugach Terrane, which is characterized by Cretaceous and later accretionary trench-fill deposits from the subduction of the Pacific plate under the southern margin of Alaska (Trop et al., 2003). The sedimentary sequences that outcrop in the valley are offset by dextral strike-slip faults associated with transpressional tectonics in the modern Matanuska valley, with the primary motion being along the Castle Mountain fault to the north and the Border Ranges fault to the south (see Figure 2 in project overview). The Chickaloon Formation is made up of fine- to medium- grained sandstones, shales, and bituminous coal. It is interpreted to have been deposited in a fluvial environment and is characterized by thick channel sand deposits, floodplain mud and coal, and thinner crevasse splay deposits (Neff et al., 2011). It represents the middle portion of a prograding fan environment.

Previous studies have tried to determine the age of the Chickaloon Formation. A minimum age of 47.8–41.3 My is provided by Ar-Ar dates of crosscutting dikes (Little and Naeser, 1989). Collett and Triplehorn (1983) report an age of about 55 My for a 2-3 m bed of tephra, however the location and methods of dating are not specified. Triplehorn (1984) further constrained the upper section of the Chickaloon to

53.3 ± 1.5 mya to 55.8 ±1.7 My via K-Ar zircon fission-track ages from two volcanic ash beds. Although these ashes are described as being a part of a the coal-rich section of the upper Chickaloon, the authors do not report the location of these samples in the section, which was exposed in a mine that has since been reclaimed. Additional efforts for dating the Chickaloon Formation were made by the previous Keck Geology Consortium project in the area, when a maximum age of ~55 My for the upper section was determined via detrital zircon fission track analysis (Merkert, 2009).

METHODS

During July and August of 2012, tonstein samples were collected from two localities over a period of four weeks. Both localities were along the Glenn Highway in the Matanuska Valley, about 70 miles north of Anchorage, Alaska. Tonstein samples were recognized based on their characteristic grey/white weathering surface with a chocolatey brown fresh surface upon exposure (Figure 1). The main field site was the open pit Evan Jones Mine that closed in 1968. Since then, various attempts have been made to reclaim the mine, including the filling of several pits. However, an exposure of Chickaloon one kilometer in length and 150 meters high still exists there, which was extensively mapped and measured during the previous Keck summer field season (Neff et al., 2011). At this location five tonsteins were sampled, including one sample that was previously known to give an imprecise age, and one that yielded a precise U-Pb zircon age of 54.8 ± 0.9 Ma, which is located stratigraphically above the 2012 samples (C. Williams, pers. comm.). One tonstein was collected from the Coyote Lake location, whose stratigraphic relationship to the Evan Jones outcrop is not known with certainty, although the tonstein from Coyote Lake is stratigraphically above a fossiliferous bed from which a new leaf-margin analysis has been made (see Reynolds, this volume).

Figure 1: Tonstein within a coal seam at the Evan Jones Mine. Photo ~1.5 m across.

Table 1. Amount of Zirconium per sample

Sample Name	Zirconium (ppm)
LGC-EJ-01	14.8553
LGC-EJ-02A	53.9286
LGC-EJ-02B	28.7722
LGC-EJ-03	9.0213
LGC-EJ-04	163.1914
LGC-EJ-04	163.3912
LGC-EJ-05	13.3777
LGC-EJ-05	13.2776
LGC-EJ-06	121.3733
LGC-EJ-08	22.0627
LGC-EJ-09	19.2152
LGC-EJ-10	31.6857
LGC-EJ-11	33.6365
LGC-CL-01	38.243

Table 1: Green (LGC-EJ-01) indicates a sample that has been successfully dated previously. Red (LGC-EJ-03) indicates a sample that contained a diverse population of zircons, which did not provide an accurate date. Samples LGC-EJ-04 and LGC-EJ-05 were run twice to assess reproducibility, which were within 1ppm of each other.

Whole rock trace element concentrations by x-ray fluorescence of tonsteins was used to evaluate potential yield of zircons as measured by ppm Zr in samples prior to selection of samples for geochronology. These data are summarized in Table 1. The sample highlighted in green (LGC-EJ-01) was found to give a precise date after a previous field season, while the sample highlighted in red (LGC-EJ-03) gave an inaccurate and imprecise date, most likely due to the influence of detrital zircons. Most of the samples that I collected were found to have more zirconium than either sample collected previously, and thus none of the 2012 samples were eliminated from further consideration based on the amount of zirconium. It is also important to note that samples 02A and 02B have considerably different zirconium levels, but were collected from what was assumed to be the same bed that had been offset by a fault.

Five samples (LGC-EJ-02A, 05, 07, 08, and LGC-CL-01) were chosen for analysis. They were chosen based on their potential to date the bottom of the Evan Jones outcrop (EJ samples) and to assign an approximate age to the Coyote Lake leaf fossils collected (CL sample). The tonsteins were processed at Pomona College, using conventional crushing, pulverizing, hydraulic (Rogers concentrating table) and gravimetric (methelyene iodide, of density 3.32) separation techniques. After concentration of heavy mineral fractions, non-magnetic zircon grains were isolated with a Frantz magnetic separator (10° side tilt, current = 1.83A). Zircons from this fraction were hand-picked with a binocular microscope to obtain a representative sample, and then cast in Epothin ® epoxy, hand polished to 1 μm with diamond films, and imaged with a K&E cathodoluminescence detector at 20 kV using Pomona College's Hitachi SU-70 Scanning Electron Microscope (Figure 2).

Zircons were dated at University of California-Santa Barbara, using a Nu Instruments Plasma HR multicollector ICPMS coupled with Photon Machines Analyte 193 nm excimer laser ablation system. Analyses were standardized to zircons 91500 and SL-1, which were analyzed regularly during the run (Kylander-Clark, 2013). Zircon $^{206}Pb/^{238}U$ ages were obtained and corrected to the ^{207}Pb to account for common lead contamination. During analysis, grains less than 95% concordant were rejected.

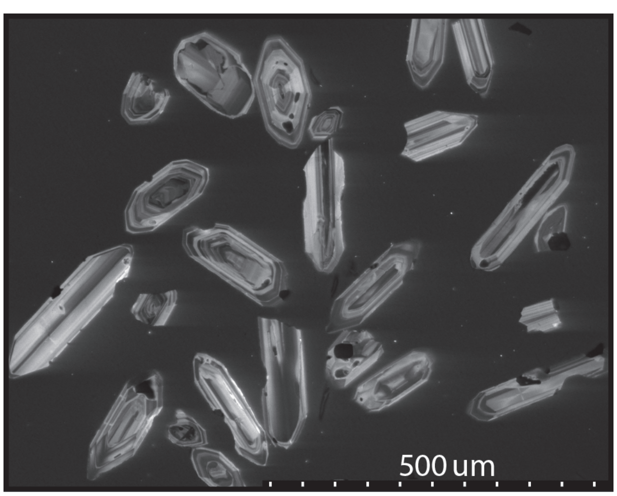

Figure 2: CL image of one sample, which shows the igneous nature of the zircons. The zircons hand-picked were the most clear and angular that could be found in the sample.

RESULTS AND DISCUSSION

After analysis, one sample, LGC-EJ-02A, clearly contains zircons that are a detrital mixture; probability density plotting shows a peak of ages in the late Cretaceous (131–70 My) and another in the Jurassic (191–164 My), which suggests that they are sourced from the ranges surrounding the valley, and not directly from Paleogene volcanic airfall. Thus, it was not included in further analysis.

In Figure 3, graphs A, B, and C represent the ages of three samples from the Evan Jones mine in stratigraphic order. They are all near the bottom of the section, with LGC-EJ-08 being the lowest tonstein that was sampled. All samples plot within error of 55 My, with subtle variations in each. LGC-EJ-08 is the oldest at 55.2 ± 0.42, but the average age for LGC-EJ-05 and LGC-EJ-07 are reversed according to stratigraphy and statistically the same, at 55.0 ± 0.45 My and 54.9 ± 0.27 My, respectively. However, it should be noted that the LGC-EJ-05 sample has a large population of grains that plot significantly below the average, whereas the others do not. This could be that an inordinate amount of sampling occurred closer to the core of the zircon grains, which would artificially cause them to seem older, whereas sampling only the rim of the grain gives a younger age. This is arguably more accurate, as it is possible that the zircon grains crystallized during protracted magmatic residence, and the rim of the grain is the last to be crystallized before it is erupted. So, it is possible that the LGC-EJ-05 sample could be found to be younger if only the rims were sampled, and the ages would better correlate to stratigraphy.

The LGC-EJ-05 sample is also interesting because, despite the fact that it provided the most clearly primary zircons, it was found to have one of the lowest concentrations of zirconium, only 13 ppm. This is significantly less zirconium than LGC-EJ-02A sample, which, despite its 54 ppm of zirconium, contained mostly detrital zircons, and only two grains of about 55 my. This could be that the zircon is concentrated if the ash is reworked, but remains relatively dilute in samples that are only lightly reworked, causing an

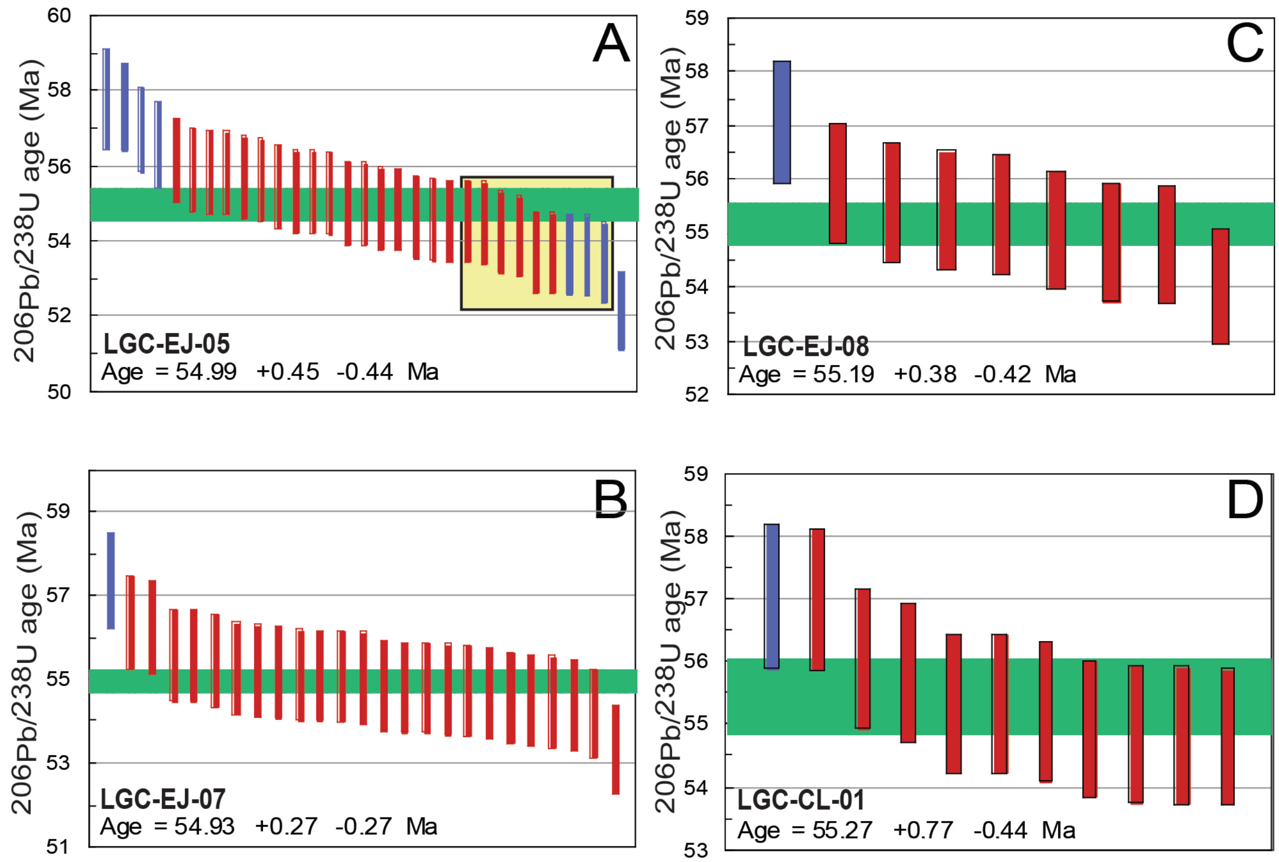

Figure 3: Dated tonsteins from Evan Jones Mine (A-C, in stratigraphic order with A being the highest) and the Coyote Lake localities. Red bars indicate samples that were more than 95% concordant, while blue bars indicate samples that were less than 95% concordant. Bar heights are 2σ. Green zone indicates the weighted mean $^{206}Pb/^{238}U$ age with error. Yellow box in A indicates unusually young samples discussed in the text.

inverse correlation between the amount of zircon and their cleanliness.

The last sample that was successfully dated was from the Coyote Lake site, whose stratigraphic relationship to the Evan Jones mine was previously unknown. The ash was sampled from a bed that was above the section that contained the leaf fossil-rich bed. It was found to have an age of 55.3 My, which suggests that temporally it lies below the Evan Jones section.

Overall, the U-Pb ages substantially refine the age of the Chickaloon formation and confirm its rapid deposition within the forearc basin. It is unlikely that the PETM (~56 My according to McInerney and Wing, 2011) is recorded in either the Evan Jones mine or Coyote Lake exposures. We can then infer that the laterally continuous negative carbon isotope excursion found during the previous Keck project (Neff et al., 2011) is the record of an early Eocene hyperthermal.

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