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Project Faculty: DAVID SUNDERLIN: Lafayette College
Project Faculty: CHRISTOPHER J. WILLIAMS: Franklin & Marshall College

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BEVERLY WALKER: Colgate University
Research Advisor: Connie Soja

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INTRODUCTION

There is growing scientific consensus that middle- to high-latitude environments are particularly sensitive to climate change (Manabe and Stouer, 1980; AICA, 2005). How the biosphere responds to and/or participates in feedback loops with this climate change is the subject of increasing attention in the earth sciences as it has bearing on predicted future climate/biosphere interactions. We, as earth historians, can investigate the ecosystem response to warmer climates at mid- to high latitudes in many northern North American Cordilleran ancient basins, particularly those that contain strata of Paleocene/Eocene age.

The pattern of temperature change across the Paleocene-Eocene boundary has been examined largely through stable isotopic and membrane lipid analysis of marine sediments. Paleotemperature estimates for the latest Paleocene and first few million years of the Eocene indicate tropical sea surface temperatures near 32°C and mid- to high-latitude sea-surface temperatures of 25°C and 17°C respectively (Sluijs et al., 2006; Zachos et al., 2006; Pearson et al., 2007). Arctic Ocean surface temperatures may have reached 24°C at the so-called Paleocene/Eocene Thermal Maximum (PETM) (Sluijs et al. 2006) and northern regions of North America were 25-30°C warmer on an average annual basis than at present (Wolfe 1978; 1985; Parrish 1998) (Fig. 1). These paleoclimatic conditions favored the development of extensive forest ecosystems from the equator to the poles.

PROJECT OBJECTIVES

The Keck Alaska 2008 project was a case study for examining the paleoecology and paleoenvironment of this extratropical region during the warmest global climate phase in the Cenozoic. The fossilized remains of early Tertiary forests exposed in the Matanuska Valley provide a high-resolution view of a mid-latitude terrestrial paleoenvironment during this major period of global warmth. Our objectives were to obtain field collections and measurements from the upper Chickaloon Formation to describe the depositional environment of the Matanuska Basin and the record of paleoecosystems preserved in the strata.
GEOLOGIC SETTING

Matanuska Basin

The Early Tertiary fore-arc Matanuska Basin in the Matanuska Valley/Talkeetna Mountains region of south-central Alaska is bounded to the south by the Border Ranges Fault system and to the north by the Castle Mountain Fault system (Fig. 2). The more than 1500m thick depositional sequence in this basin includes the fluvi-lacustrine to alluvial Chickaloon Formation as the lowermost unit. This formation unconformably overlies the marine, ammonoid-bearing Cretaceous Matanuska Formation of the Peninsular terrane component of the Wrangellia composite terrane. The Chickaloon itself comprises a heterogeneous suite of facies that preserve a diverse plant fossil assemblage (Hollick, 1936; Wolfe et al., 1966). A late Paleocene-early Eocene age has been assigned to the Chickaloon Formation on the basis of plant megafossils, palynology, and isotopic ages of interbedded volcanic tuffs (55.8 to 52.2 Ma) from the upper portion of the formation (Ames and Riegel, 1962; Wolfe et al., 1966; Triplehorn et al., 1984). Paleocurrent data (Trop et al., 2003) indicate that sediment sources for the Chickaloon were from uplift related to Castle Mountain Fault and Border Ranges Fault activity at the time of deposition. Sediments were then transported toward at least one trunk stream that drained the basin. The numerous bituminous coal deposits that characterize the northern and southern margins of the basin during and post-Chickaloon deposition. The Wishbone Formation, a massive conglomerate about 900 m thick, and the variably thick Arkose Ridge Formation (Trop et al., 2003) represent coarser alluvial facies that overly the Chickaloon in scattered outcrops that are laterally variable across the area (Winkler, 1992). The Wishbone and Arkose Ridge units indicate continued, syndepositional tectonic activity and the encroachment of extrabasinal depositional regimes as the basin matured (Trop et al., 2003)(Fig. 3).

During the early Tertiary, this entire fore-arc basin was located between an accretionary prism that formed to the south (paleowest?) and a volcanic arc to the north (paleoeast?) coincident with northward subduction beneath the Wrangellia composite terrane. This complex developed south of the present latitude of the Matanuska Basin and then moved northward through dextral offset during the Late Cretaceous-early Tertiary. Paleomagnetic data from the Paleocene-Eocene strata indicate that the position of the developing basin was ca. 1600 ± 1200
km (14° ± 11° of latitude) south of its present latitude (61.7° N) during deposition (Stamatakos et al., 1989). It apparently reached its present latitude by ca. 50-45 Ma (Stamatakos et al., 1988; Hillhouse and Coe, 1994).

**Evan Jones Mine**

Our field site at the Evan Jones Mine north of Sutton, AK exposed nearly 1 km of laterally-continuous terraced outcrop on the north side of Wishbone Hill. (Figs. 4 and 5). This coal mine was recently reclaimed and is well known to contain abundant wood fossils and a diverse leaf assemblage (Sunderlin et al., 2007). The uppermost Premier Coal Zone is exposed at the base of the outcrop with the Jonesville Coal Zone comprising the remaining thickness up section to the Wishbone Fm. contact. The exposure is cut by several small normal faults with less than 20 meters of offset on each. Our team also studied smaller exposures along strike to the east and west of the main face indicated on Figure 4.

**STUDENT PROJECTS**

The field portion of this project ran from July 1st to 28th, 2008 and was focused on Wishbone Hill exposures of the Chickaloon Fm. Participants worked both individually and in teams to collect stratigraphic, geochronological, and paleontological data. We have briefly summarized each student’s focused work below and refer the reader to the student paper in this volume for detailed results.

Garrison Loope (Oberlin College) analyzed stratigraphically tied leaf collections from fossiliferous horizons for indications of paleoclimate. He used leaf margin analysis, leaf area analysis, and Climate Leaf Analysis Multivariate Program (CLAMP) methods to estimate temperature and precipitation at the time of Chickaloon deposition.

Douglas Merkert (Union College) collected sandstones within the coarser deposits in the section (channel, crevasse splays) for zircon analyses. His work provides both a maximum age constraint on

![Figure 3. Matanuska Basin depositional reconstruction. Chickaloon sedimentation is represented by the lowland fluvial region along the basin midline. Coeval and overlying Wishbone deposits represent basin margin deposits. Modified from Trop et al. (2003).](image-url)
John Neff (Amherst College) focused on facies analysis and determining the stratigraphic architecture of the Chickaloon exposures at Wishbone Hill. He measured more than 20 stratigraphic sections across the field site and constructed a detailed depositional model. His analysis of the carbon isotope record through the section shows interesting ties to facies shifts in the unit.

Nancy Parker (Lafayette College) utilized the leaf collections from the same beds as Garrison Loope in an analysis of plant insect interactions preserved as traces of herbivory on the angiosperm leaves. Her work represents the highest latitude investigation of this sort of palaeoecological data in the Paleocene/Eocene on North America. Her findings show low incidence of herbivory in Chickaloon leaves despite warmer palaeotemperatures.

Kyle Trostle (Franklin & Marshall College) investigated the mineralogy and geochemistry of the extensive fossil wood deposits in the Chickaloon. His work indicates that the fossil conifer (Metasequoia) wood was permineralized in a multi-stage processes. The mineralogy of the dominant permineralization phase varied stratigraphically and may be related to changes in basin subsidence.

Beverly Walker (Colgate University) performed the first detailed analysis of the gastropod fauna from the Chickaloon Formation. She collected both shells and gastropod opercula from stratigraphically tied beds along the exposure. Her close examination of these viviparid snails shells indicate possible predation marks recorded in the growth history of the shells and gives a glimpse into faunal paleoecology in the unit.

PROJECT RESULTS

The team and individual student projects at our study site comprise the most aggressive investigation into the paleoecology and paleoenvironment of the Chickaloon Formation yet attempted. Here we highlight our team’s findings but direct the reader to the individual student papers for more detailed observations.

Paleoenvironment & Paleoclimate of upper Chickaloon deposition

Field evidence suggests that the upper Chickaloon Formation was deposited in a dynamic fluvial/alluvial depositional environment with laterally...
discontinuous crevasse splay layers punctuating variably organic rich fine-grained sedimentation on the floodplain. The faunal and floral remains as well as the mineralogy of the fossil wood recovered from these strata also suggest the frequent occurrence of standing water conditions. Large infrequent channel deposits outcrop to the west of the main exposure at the Evan Jones mine and lead us to believe that most of the study area is composed of strata deposited some distance from a trunk stream. Paleoclimate analyses by leaf physiognomy methods indicate that the mean annual temperature at the time of deposition was significantly warmer than at present (~10-14°C in the early Eocene vs. ~2°C in the Recent). The analysis of in situ fossil wood associated with coal-forming facies indicates large stature vegetation and high biomass productivity on par with other coeval high latitude forests in Arctic Canada (Williams, 2007).

Paleoecology & Paleoecosystem Structure of Eocene Southern Alaska

Our detailed examination of fossil remains from the Chickaloon Formation has also shed light on complex ecosystem interactions in early Eocene southern Alaska. Taxodiaceous redwoods dominated coal-forming facies whereas the better-drained floodplain areas hosted a more diverse assemblage of broad-leaf angiosperms. Though less frequently damaged than coeval floras further south in North America, the fossil leaves from the Chickaloon show evidence of four of the five main herbivory guilds. *Metasequoia* amber preserved in organic rich shales near coal horizons in the Premier Coal Zone has yielded the first discovery of insects in rocks of this age from Alaska. These insects include members of the Hymenoptera (ants) and Hemiptera (aphid nymphs). The occurrence of the snail taxa *Bellamya* and *Campeloma* (Viviparidae) indicate freshwater conditions.

As the reader will see, our team’s multifaceted and integrated analysis of this rich locality has already yielded results that provide new understanding of the geologic and paleoenvironmental history of the Chickaloon Formation. These data then have importance in a broader context as well as they inform models of the accretion history of the Northern Cordillera and offer a rare glimpse into mid-high latitude paleoecological and paleoclimatic conditions during a “hothouse” climate.

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REFERENCES


