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Research Advisor: Tim White

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MARIA PRINCEN: Macalester College
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CONOR P. MCNALLY:
The Pennsylvania State University
Research Advisor: Tim White

INTRODUCTION

Carbon isotope chemostratigraphy can be a powerful chronostratigraphic tool for those time periods in which carbon isotope profiles have been well constrained by radiometric age dates. In this study the carbon isotope data from paleosol bearing intervals in the Kootznahoo Formation, southeastern Alaska are presented. The results suggest that the globally widespread Paleocene-Eocene Thermal Maximum (PETM) Carbon Isotope Excursion (CIE) exists within the Kootznahoo Formation, and therefore provides an additional timeline for understanding the history of sedimentation and basin evolution of Paleogene southeast Alaska.

BACKGROUND

The Kootznahoo Formation, named from Kootznahoo Inlet, Admiralty Island, Alaska, was first described by C. W. Wright in 1908 and is composed primarily of sandstone and conglomerate with minor local deposits of silt, shale, lignite, and coal (Loney, 1964; Lathram, 1965). These deposits are interpreted to be dominantly non-marine in origin (Lathram and Pomeroy, 1965). The formation lies with marked angular unconformity on older Triassic and Cretaceous rocks and is in turn overlain by non-marine volcanic flows of the Admiralty Island Volcanics (AIV) (Loney, 1964).

Wright's original 1908 descriptions erroneously assigned the formation to the Mesozoic Era, an age misrepresentation repeated by later workers, for example a late Jurassic to Cretaceous age assignment by Lathram (1965). However, the discovery of Eocene (Loney, 1964) and Oligocene (Wolfe, 1977) plant fossils helped end the debate, although the total amount of time represented by the formation is unclear and is one focus of the present work.

The Kootznahoo Formation crops out in tidal zones and typically is intensively weathered. The formation was estimated by early workers to be approximately 400 m thick (Loney, 1964) but additional estimates range from 460 m (Muffler, 1967) to 600 m (Loney, 1964) to as thick as 1500 m (Lathram, 1965). The estimates likely included stratigraphic measurements of igneous rocks including felsic volcanics and gabbro in the outcrop sections. These igneous rocks are most likely primarily dikes and sills emplaced during volcanism associated with the basaltic andesite flows of the overlying AIV (Lathram, 1965).

The formation can be observed in four main outcrop areas including Keku Strait, Pybus Bay, Kootznahoo Inlet, and Zarembo/Prince of Wales Islands (Dickinson and Vuletich, 1990). However, it is unclear whether deposition of Kootznahoo sediments occurred in multiple or a single depositional basin(s), a question that is another focus of the present research.

During mid-late Cretaceous time, Southeast Alaska experienced regional metamorphism, penetrative deformation , and pluton emplacement associated with the accretion of the Wrangellia Composite Terrane (e.g. Crawford et al., 1987; Gehrels et al., 2009). Post Cretaceous deformation caused emergence and erosion, and a sub-aerial basin formed in the Paleogene, perhaps by faulting (Lathram, 1965). Reconstructions of the Paleogene basin indicate that steep-gradient streams flowing from rugged mountains of folded Mesozoic and Paleozoic rocks cut through alluvial fans (Loney, 1964), coalesced into braided streams and entered an intermontane basin (Lathram, 1965). In the more distal portions of the depositional basin lakes and swamps existed under a humid climate regime (Loney, 1964) that eventually led to the development of thin discontinuous coal seams (Loney and Lathram, 1965).

Lathram (1965) considered Kootznahoo Inlet to have been the primary Kootznahoo Formation depocenter. Noting that there are no known overlying volcanics on Paleogene rocks in Kootznahoo Inlet, and that basaltic flows are a feature confined to the Southern Admiralty area (and further south around Kake), he concluded that Kootznahoo deposition occurred in two basins (Lathram, 1965). Alternatively, Muffler (1967) suggested that Kootznahoo sediments were deposited into a single elongate basin of the Admiralty Trough. In his reconstruction, subsequent uplift dissected the single basin deposits and only erosional remnants now remain. This author also suggested that sediment source areas existed at great distances on both sides of the trough (Muffler, 1967).

Recently USGS scientists embarked on a more detailed stratigraphic and sedimentologic assessment of the Kootznahoo Formation. The results of this work are in preparation (White, Haeussler, and Karl, in preparation) and include, in part, the following observations:

1) A mostly continuous stratigraphic section exposes a basal unconformity through to overlying AIV dated at approximately 25 Ma on southern Admiralty Island, while on Kupreanof Island, a series of outcrops separated by previously mapped felsic volcanics and gabbro are considered to represent a continuous stratigraphic section beginning with the basal unconformity. Furthermore, on nearby Kuiu Island, a series of Kootznahoo outcrops also separated by felsic volcanics and gabbro culminate in interbedded Kootznahoo/AIV dated at 26-25 Ma.

2) A prominent well-developed paleosol exists in approximately the same stratigraphic position relative to the AIV in outcrops on Kuiu and southern Admiralty Island.

The prominent well-developed paleosol appears to have formed during the PETM and therefore may serve as a stratigraphic marker bed, in effect, an age date since the PETM is globally well dated at approximately 55.9 Ma. The PETM age assignment is based on the presumed stratigraphic position of the Kuiu Island paleosol relative to a radiometric age date from Kupreanof Island (53.5 +/- 0.6 Ma), the presence of fossil remains of palm and the cycad *Dioon* of Late Paleocene age (Wolfe, pers. comm., 2002) associated with the paleosol on southern Admiralty Island, and the existence of a prominent, well developed paleosol associated with the PETM throughout western North America (White et. al, 2006).

In this study we present the results of a high-resolution carbon isotope chemostratigraphic analysis of the prominent paleosols on Kuiu and southern Admiralty Island and suggest that they are coeval and contain the well-documented PETM carbon isotope excursion.

METHODS

Samples containing visible organic carbon were collected from Little Pybus Bay, southern Admiralty Island, and Kadake Bay, Kuiu Island (Fig. 1, Davidson et al., this volume). Samples were taken at both sites starting at the base of the well-developed paleosol and continuing up section at 10cm intervals. Samples were returned to Penn State University where they were air dried, powdered using a micro-drill, and acid treated to remove any carbonate cement.

Carbon isotopic analyses were accomplished using the Costech Elemental Combustion System in the Penn State Department of Geosciences Mass Spectrometry facility. Approximately 1.0-1.5mg of each micro-drilled sample was placed in a tin cup. Combustion of the organic carbon-containing samples occurred at 1000o C in an atmosphere of O_2 resulting in the formation of CO_2. The isotope ratio method with no dilution was used.

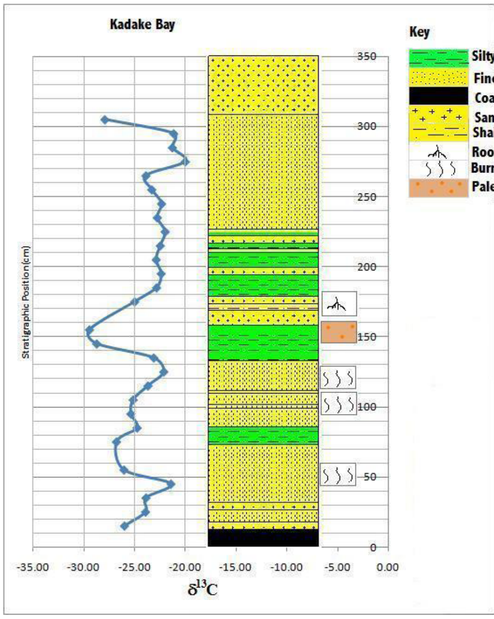

Figure 1 – Lithologic and $\delta^{13}C$ profile of the paleosol-bearing section measured in Kadake Bay, Kuiu Island, Southeast Alaska.

The mass spectrometer software was used to calculate $\delta^{13}C$ values by measuring the ratio of m/z 45 versus m/z 44 using the peak area. Final $\delta^{13}C$ values were determined by referencing to internal standards used to calibrate the system. Variable weights of standards were used to bracket linearity effects.

RESULTS.

Figure 1 displays the lithologic description and $\delta^{13}C$ variation of the paleosol-bearing outcrop in the Kadake Bay sedimentary section. Overall the paleosol-bearing section is composed of fine sand and silty shale with sparse interbeds of sandstone. The basal portion of the section is pervasively burrowed, most notably at the 50, 100, 120 and 175 cm levels. A prominent rooted paleosol with redoximorphic features exists at the 153cm mark.

Of note in the δ13C profile is the abrupt decrease from a baseline value of approximately –25 ‰ to a peak depletion value of -29.9 ‰ at 155cm in the sampled stratigraphic column. A second abrupt $\delta^{13}C$ increase is visible from 295 to 305 cm.

Figure 2 displays the lithologic description and $\delta^{13}C$ variation of the paleosol-bearing outcrop sampled in Little Pybus Bay. The Little Pybus Bay section is predominately composed of very fine grained sandstone and silty shale. The sampled section is rooted throughout and contains many fossil leaf-bearing horizons. Large in situ stumps exist at the 80 -100 cm level in the measured and sampled section.

At Little Pybus Bay a similar, though larger depletion in $\delta^{13}C$ values exists with $\delta^{13}C$ values as low as -31.5 ‰ at 70 cm in the profile compared to baseline values of approximately -25‰ (Fig. 2). A second decrease in $\delta^{13}C$ value to approximately –27‰ is visible toward the top of the paleosol-bearing section at the 210 -240 cm level.

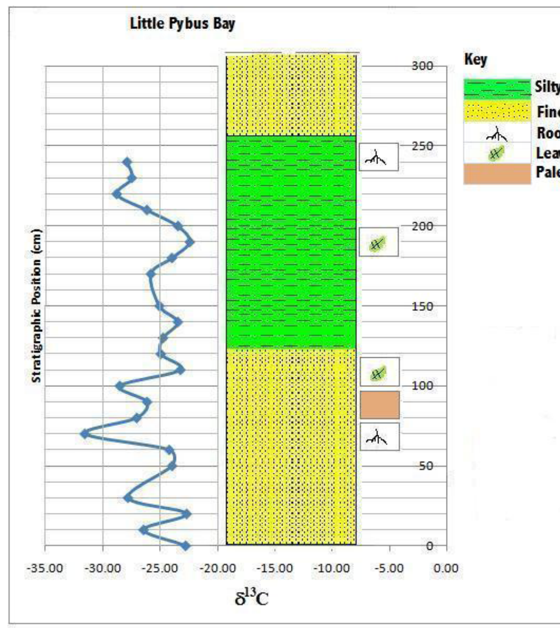

Figure 2 - Lithologic and $\delta^{13}C$ profile of the paleosol-bearing section measured in Little Pybus Bay, Admiralty Island, Southeast Alaska.

DISCUSSION

The Kootznahoo Formation is considered to have been deposited in a mostly non-marine setting, and rooted, immature paleosols are visible in various intervals throughout the formation. Prominent well-developed paleosols were visible at only two locations in the study area.

At Little Pybus Bay a well-developed paleosol exists within a light grey to yellow siltstone to shaley siltstone matrix overlying a horizon of dark grey to black carbonaceous shale with light grey to orange siderite concretions (Fig. 2). Several large meter-scale in situ fossil stumps exist within the grey to yellow siltstone. The paleosol is positioned approximately fifty meters below the base of the AIV.

At Kadake Bay the paleosol consists of light grey silty shale with olive and light red redoxymorphic features and is rooted throughout. The upper half of the paleosol is pervasively red, and is positioned approximately sixty meters below the base of the AIV in the Port Camden region.

Rooted zones in fluvial depositional settings are common and represent colonization of the substrate by higher plants. In these fleeting "moments" between sedimentation events in an active depositional regime, mature soil profiles are typically not developed. In contrast, the well-developed paleosols, in this case exhibiting strong horizon development, represent an episode of emergence and landscape stability. Combined with the equivalence of their relative stratigraphic position to the AIV, this observation suggests that the paleosols at the two outcrop study sections are coeval.

In the background we outlined the rationale for an association between the studied paleosols and the PETM. An abrupt large CIE is known to mark the PETM in deep marine sediments (Kennett and Stott, 1991). The PETM CIE has also been observed in continental sections, for example, paleosol carbonate nodules from the Big Horn Basin (Koch et al., 2003) and in terrestrial organic carbon in continental strata (e.g., Yans et al., 2006; Domingo et al., 2009). The Yans et al. (2006) profile from Wyoming is particularly revealing because it displays the PETM CIE as ranging from a baseline of -25 ‰ to a peak of -29‰, very similar to the excursion revealed in the Kootznahoo paleosols.

We interpret the abrupt high amplitude CIE associated with the prominent paleosol as a record of the PETM in southeast Alaska; therefore, an age of approximately 55.9 Ma, as outlined in Westerhold et. al, 2009, can be assigned. While this date provides a much needed age constraint for understanding Kootznahoo sedimentation and basin evolution, its stratigraphically high position leaves much of the formation chronostratigraphically unconstrained with the basal unconformity developed during or before the late Paleocene. Furthermore, the conclusion that the paleosols are coeval, representing an episode of landscape stability, suggests that the outcrops on both sides of Fredrick Sound (Little Pybus Bay and Kadake Bay) were most likely deposited in a single basin. However, the evidence presented here does not allow for a determination of the relationship between these outcrop sections and the Kootznahoo Inlet sectionsto the North.

CONCLUSION

A prominent well-developed paleosol in the Kootznahoo Formation, southeast Alaska, existing at two locations separated by about 50 km (Fig. 1, Davidson et al., this volume) is located in approximately the same stratigraphic position relative to the AIV. The paleosols contain a prominent CIE, and given the amplitude of the CIE and other chronostratigraphic constraints, the CIE is best assigned to the PETM. Therefore, the prominent PETM CIE provides a date of ~55.9 Ma for the well-developed paleosol within the upper portion of the Kootznahoo Formation.

While any date represents great progress in understanding the Kootznahoo Formation, the full range of time recorded in the formation remains unclear. The majority of the formation must have been deposited in the late Paleocene (or older). More work on age dating the basal portions of the Kootznahoo Formation must be accomplished. Kootznahoo deposition in the south Admiralty and Kuiu Islands region is considered to have been into a single depositional basin, however the work presented here provides no insight into the relationship to Kootznahoo Formation outcrops at Kootznahoo Inlet to the north.

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