KECK GEOLOGY CONSORTIUM

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

April 2009
Franklin & Marshall College, Lancaster PA.

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2008-2009 PROJECTS

THE BLACK LAKE SHEAR ZONE: A POSSIBLE TERRANE BOUNDARY IN THE ADIRONDACK LOWLANDS (GRENVILLE PROVINCE, NEW YORK)
Faculty: *WILLIAM H. PECK*, *BRUCE W. SELLECK* and *MARTIN S. WONG*: Colgate University
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PALEOECOLOGY & PALEOENVIRONMENT OF EARLY TERTIARY ALASKAN FORESTS, MATANUSKA VALLEY, AL.
Faculty: *DAVID SUNDERLIN*: Lafayette College, *CHRISTOPHER J. WILLIAMS*: Franklin & Marshall College
Students: *GARRISON LOOPE*: Oberlin College; *DOUGLAS MERKERT*: Union College; *JOHN LINDEN NEFF*: Amherst College; *NANCY PARKER*: Lafayette College; *KYLE TROSTLE*: Franklin & Marshall College; *BEVERLY WALKER*: Colgate University

SEAFLOOR VOLCANIC AND HYDROTHERMAL PROCESSES PRESERVED IN THE ABITIBI GREENSTONE BELT OF ONTARIO AND QUEBEC, CANADA
Faculty: *LISA A. GILBERT,* Williams College and Williams-Mystic and NEIL R. BANERJEE, U. of Western Ontario
Students: *LAUREN D. ANDERSON*: Lehigh University; *STEFANIE GUGOLZ*: Beloit College; *HENRY E. KERNAN*: Williams College; *ADRIENNE LOVE*: Trinity University; *KAREN TEKVERK*: Haverford College

INTERDISCIPLINARY STUDIES IN THE CRITICAL ZONE, BOULDER CREEK CATCHMENT, FRONT RANGE, CO
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Students: *EVEY GANNAWAY*: The U. of the South; *KENNETH NELSON*: Macalester College; *MIGUEL RODRIGUEZ*: Colgate University

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Students: *AVERY R. COTA*: Minnesota State University Moorhead; *JANE DIDALEUSKY*: Smith College; *ROWAN HILL*: Colorado College; *ANNA PENDLEY*: Washington and Lee University; *MAIJA SIPOLA*: Carleton College; *STACEY SOSENKO*: Franklin and Marshall College

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Faculty: *NICHOLAS E. BADER and ROBERT J. CARSON*: Whitman College; *A. BAYASGALAN*: Mongolian University of Science and Technology; *KURT L. FRANKEL*: Georgia Institute of Technology; *KARL W. WEGMANN*: North Carolina State University
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BLOCK ISLAND, RI: A MICROCOSM FOR THE STUDY OF ANTHROPOGENIC & NATURAL ENVIRONMENTAL CHANGE
Faculty: *JOHAN C. VAREKAMP*: Wesleyan University and *ELLEN THOMAS*: Yale University & Wesleyan University
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Keck Geology Consortium: Projects 2008-2009
Short Contributions – Alaska

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GEOCHEMISTRY, MINERALOGY, AND MORPHOLOGY OF FOSSIL WOOD FROM THE LATE PALEOCENE-EARLY EOCENE CHICKALOON FORMATION

KYLE TROSTLE: Franklin and Marshall College
Research Advisor: Christopher J. Williams

INTRODUCTION

The early Cenozoic Chickaloon Formation (Fig. 1) is known for its abundant fossil woods. Within these fossil woods, there is a striking variation in appearance and preservation (Fig. 1). The main goal of my project was to characterize the differential permineralization of fossil wood recovered from different Chickaloon Formation strata. I also assessed the intra-sample heterogeneity in mineralogy with the goal of understanding the mechanism(s) leading to differential permineralization of fossil wood.

GEOLOGIC SETTING

The Chickaloon Formation is part of the Matanuska Valley–Talkeetna Mountains forearc basin, and lies within the modern day Matanuska Valley in Alaska (Sunderlin and Williams, this volume). This formation is composed of nonmarine strata that are Paleocene to Oligocene in age (Trop et al., 2003). The paleomagnetic data from the Paleocene- to Eocene-aged strata of the Matanuska Valley–Talkeetna Mountains forearc basin suggest that the early sediments of this formation were deposited

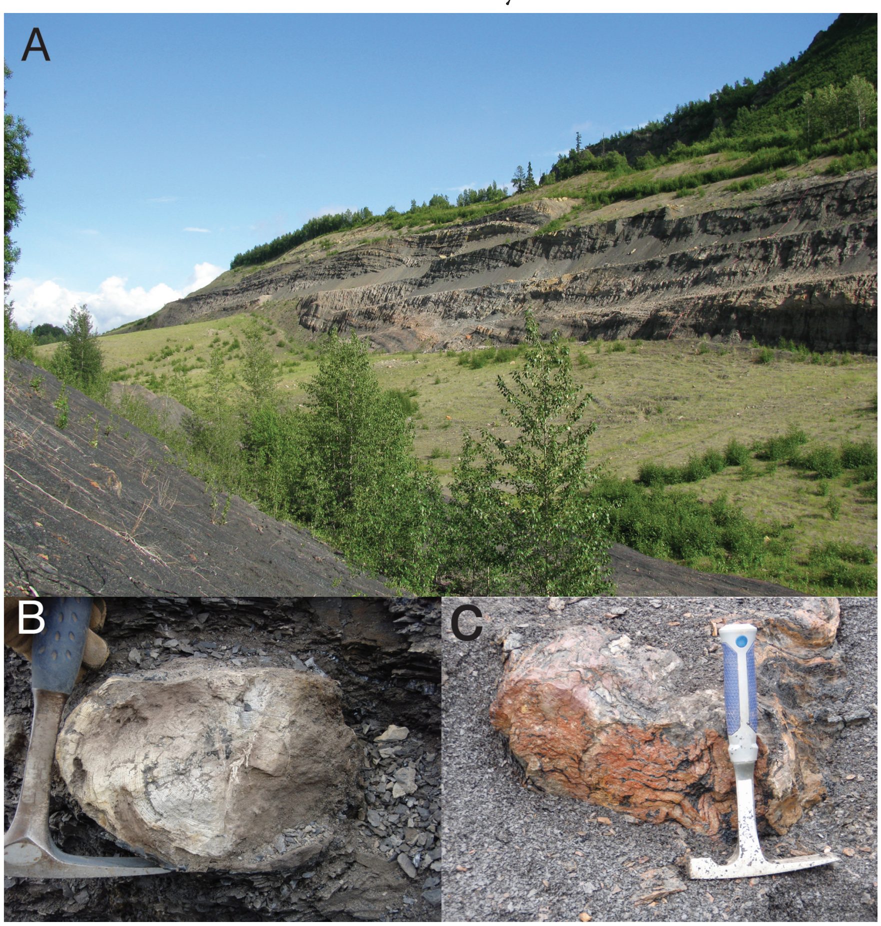


Figure 1: The Chickaloon Formation strata at the Evan Jones Mine (A) and fossil wood from Jonesville Coal Zone (B) and lower Premier coal zone (C).

~1600 ± 1200 km south of their present day latitude (Stamatakos et al., 1989). By 50 to 45 Ma ago, the basin is thought to have been at its present latitude, through the interpretation of a variety of paleomagnetic data (Trop et al., 2003).

The Chickaloon Formation itself is composed of nonmarine strata; it consists of ~1500 m of mudstone, sandstone and coal (Trop et al., 2003). These mudstone, sandstone, and coal layers, along with minor conglomerate and volcanic tuff, contain a veritable treasure trove of fossils, from tree stumps more than a meter across to snails much smaller than a centimeter in diameter. These layers have been characterized into two lithofacies by Trop et al. (2003). The lithofacies present at the Evan-Jones mine outcrop is comprised of channelized fine-grained sand, along with shales, carbonaceous shales, and coals. This lithofacies is broadly interpreted as a floodplain sequence although considerable local-scale variation exists (see Neff, this volume).

METHODS

The bulk chemistry of the fossilized wood samples was assessed using the XRF technique for whole rock chemical analysis as outlined on the Franklin and Marshall College website, http://www.fandm.edu/x7985. One slight change was made to the procedure, through the addition of another loss on ignition step; this step removed organics from the samples by heating them for 4 ½ hours in a 450 °C muffle furnace. XRF standards were prepared for high calcite, high iron, and high silica samples by using the Jls-1, Fer-1, and Jch-1 standards for both major and trace analyses. The bulk chemistry of fossil wood was calculated for multiple samples in each stratigraphic layer and statistically compared between strata to reveal significant differences in bulk chemistry.

XRD analyses were run on the ground wood matrix, as well as large intrusions within the samples. The XRD technique is outlined on the Franklin and Marshall College website, http://www.fandm.edu/x7985.

Seven fossil wood samples from the Jonesville and Premier coal zones were thin sectioned by Spectrum Petrographics. A variety of in-house thin sections were also created, although the thickness for these thin sections is not as well constrained (as they were primarily for anatomical analyses). Thin sections were also stained using the technique outlined by Dickson (1966) to help distinguish carbonate phases.

Isotope analyses of the fossil wood matrix material were also conducted at the INSTAAR isotope lab (University of Colorado, Boulder), where carbonate samples were analyzed for $\delta^{18}O$ and $\delta^{13}C$.

RESULTS

Bulk chemistry revealed stratigraphic trends in the chemistry of the fossilized wood. Iron tends to be a large percentage of the wood matrix low in the stratigraphic section, whereas calcium is a large percentage of the wood matrix high in stratigraphic section. Lanthanum, manganese, nickel, ytterbium, zinc, and scandium trends followed those of iron, being higher in concentration in the low strata. Magnesium concentrations tended to be statistically lower only in the lowest strata. Strontium and zirconium were highest within samples from the CW strata of the Jonesville coal zone (Fig. 2).

XRD analyses revealed that calcite and dolomite were the dominant mineral phases in wood matrix in high strata. In some samples, a significant amount of quartz was also present in the matrix material high in stratigraphic section. Low in stratigraphic section, siderite became the dominant mineral phase, but small amounts of quartz were also present. XRD analyses of sample intrusions revealed that most were either composed of calcite, dolomite (ankerite), or quartz.

Mineralogic thin sections and staining illustrated a variety of interesting permineralization structures in the wood, as well as the diversity of carbonate phases involved in permineralizing the woody material itself. Structurally, thin-walled earlywood

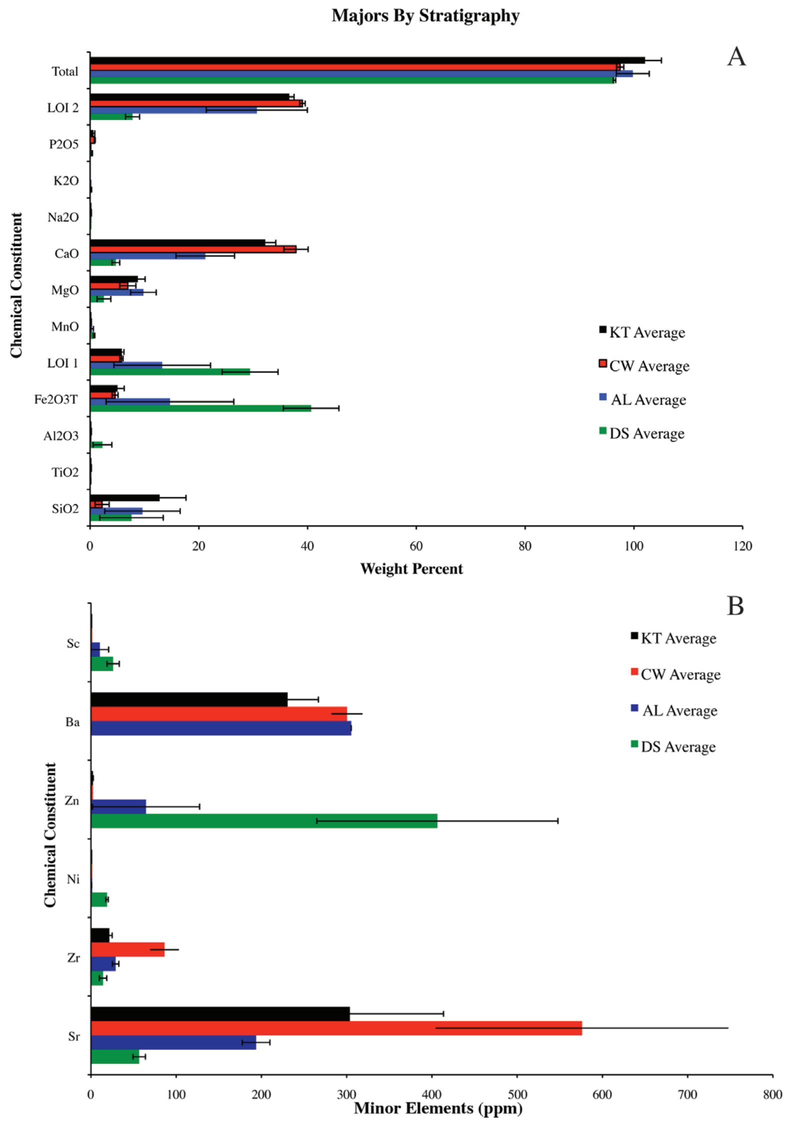
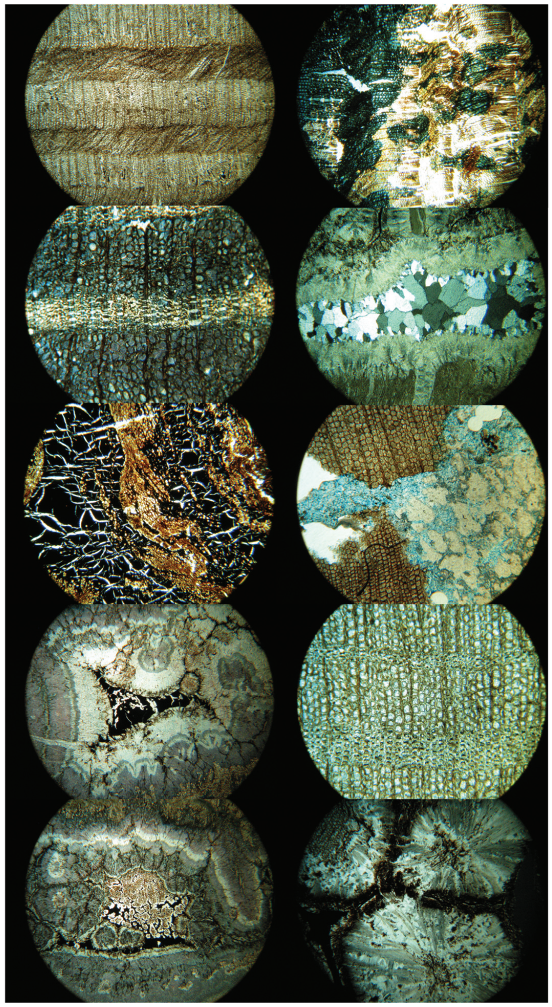


Figure 2: Major (A) and minor (B) bulk chemistry data of wood matrix material reveal differences in bulk chemistry by stratum (KT is the highest stratum in Jonesville coal zone, DS is the lowest stratum in Premier coal zone). Error bars are plus or minus 1 standard error of the mean.

tracheids tend to be less competent than thicker-walled latewood tracheids, and tend to deform preferentially (Fig. 3A). Earlywood tracheids tend to be permineralized from within the cell lumen by ferroan calcite, whereas latewood tracheids tend to be permineralized from the intercellular cavities between cells and also tend to be permineralized with dolomite (Fig. 3B). Examination of the differences between the preservational quality of samples in different strata revealed that lower strata samples were permineralized with siderite and dolomite, and were more deformed than those samples high in stratigraphic section (Fig. 3C).

Other thin section features include regions of coalified organic material surrounded by botryoidal fans of calcite (Fig. 3D). There are also regions of organic matter preserved by drusy quartz surrounded by these botryoidal fans of calcite as well (Fig. 3E). Further, there are regions where late stage quartz has replaced the permineralizing carbonate phase, but retained some of the original organic structure and relict carbonate textures (Fig. 3F).

Intrusions into the Jonesville coal zone samples tend to have a variety of intruding phases. Phases include: micrite, replete with vadiods; botryoidal cal-



A: Earlywood (EW) preferential deformation in "kink bands". Plane polarized light, 40x.

B: Differential permineralization between earlywood (EW) and latewood (LW). Section stained, plane polarized light, 100x.

C: Extensive deformation and coalification in wood from the lower strata. Plane polarized light, 40x.

D: Coalified organic matter surrounded by botryoidal calcite and dolomite. Stained section, plane polarized light, 40x.

E: Organic material preserved by drusy quartz (Qd) surrounded by botryoidal calcite and dolomite. Stained section, plane polarized light, 40x.

F: Late replacement of carbonates by quartz within areas of petrified wood. Stained section, plane polarized light, 40x.

G: Petrified wood from high strata intruded by micrite, botryoidal carbonates, and finally, drusy quartz. Crossed polarizers, 40x.

H: Vein of calcedony and micrite within petrified wood from low strata. Stained section, plane polarized light, 100x.

I: Well preserved earlywood (EW) and latewood (LW) from a high stata sample. Note latewood distortion of organic matter. Plane polarized light, 40x.

J: Force of crystallization sequesters organic matter in pockets (arrows). Crossed polarizers, 40x.

Figure 3: Mineralogic thin sections expose wood structures and permineralization fabrics, textures, and contacts. Note some sections are stained with alizarin red and potassium fericyanide (Dickson, 1966).

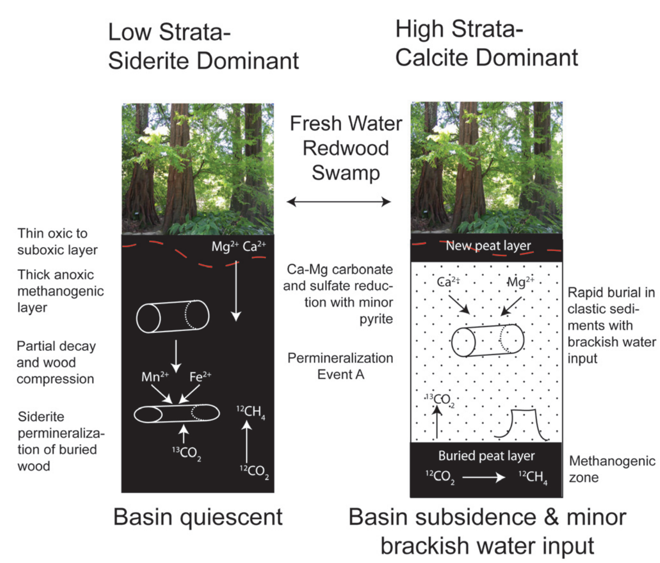


Figure 4: Model B, the differential permineralization of fossil wood based on depositional changes.

cite; and drusy quartz (Fig. 3G). Intrusions varied greatly between samples however, and all of these phases only appear together in some of the stratigraphically high samples. Intrusions into samples low in stratigraphic section also include micrite, drusy quartz, and chalcedony phases (Fig. 3H).

Thin section textures also include regions where organic matter has been pushed around and distorted by the force of growing crystals (Minguez et al., 1994). The latewood tracheids of many samples from higher strata often appeared to have suffered from this phenomena (Fig. 3I). In some cases this force of crystallization actively sequestered large amounts of organic matter into small areas (Fig. 3J).

Isotope data exposed that the carbonate that permineralized the wood tended to have a high positive $\delta^{13}C$ ratio (average = +7.4‰) and also a negative $\delta^{18}O$ ratio (average = -12.5‰).

DISCUSSION

Two models were developed in order to adequately explain both the permineralization process within a single fossil wood sample, and to explain the variance in the dominant permineralizing phase of samples in different strata. The first model, Model A, is composed of 11 steps of permineralization.

1) Compaction of sediments causes "kink banding."

2) Permineralization Event A precipitates ferroan calcite within earlywood cell lumens and dolomite within latewood.

3) Brittle deformation of permineralized material.

4) Infilling of micrite.

5) Botryoidal calcite growth.

6) Resorption texture as environmental conditions change.

7) Quartz precipitation.

8) Coalification process.

9) Cleating of coal as volatiles are driven off.

10) Late stage carbonate recrystallization

11) Weathering of samples upon exposure.

The second model, Model B, explains the inter-stratum differences in the carbonate phase deposited during Permineralization Event 1, as well as the differential preservation of the samples (Fig. 4).

In a waterlogged peat typical of the coal facies, the initial carbonate phase precipitated would be siderite, as the reducing conditions in the peat allowed for the mobilization of iron and manganese. Methanogensis, rather than sulfate reduction, was likely the dominant anaerobic microbial process in the peat due to low sulfate concentrations as is typical of freshwater swamps (Moore et al., 1992). This scenario would occur in an inactive or slowly subsiding basin resulting in slow organic matter accumulation rates, extensively deformed wood structure and siderite-dominated permineralization, and would result in the positive $\delta^{13}C$ ratio of the carbonates.

At some point, however, the basin became more active and subsided faster, allowing some marine influence to partially displace the zone of methanogenesis downward. In the swamp, trees were rapidly buried in clastic sediments as channel gradients increased. Sulfate reduction occurred around these trees in the clastic sediments influenced by marine solutes, and calcium-magnesium carbonates, along with minor pyrite were precipitated, preserving the trees. This scenario explains the calcite and dolomite permineralization of those trees found in high strata. Carbonate carbon and oxygen isotope data suggest, however, that the carbonate formed from CO_2 generated in a methanogenic environment dominated by meteoric water inputs. The displaced methanogenic zone maintained in buried peat layers was therefore the source of the isotopically heavy $\delta^{13}C$ and light $\delta^{18}O$ carbonate that combined with the marine cations to permineralize the wood.

This explanation for the difference in bulk chemistry as well as deformational and preservational extent of fossilized trees from different strata arises from models postulated by Moore et al. (1992), and Matsumoto et al., (1981) with modifications. These models chronicle the precipitation of different carbonate phases in concretions through time in a subsiding modern marsh sequence, as well as in Japanese Paleogene coalfields.

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