WOODY DEBRIS LENSES: PALEOENVIRONMENTAL ARCHIVES

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INTRODUCTION

Woody debris lenses (WDL) are found with remarkable preservation throughout the Beaufort Formation on northern Banks Island in Arctic Canada. This arctic locality preserves unaltered wood and plant material within loose, unconsolidated sediments. Macrofloral debris is found scattered vertically and laterally throughout the formation but is heavily concentrated in dense WDL. These lenses serve as a storehouse of paleoenvironmental information. WDL contain macrofossils (large pieces of wood, sometimes whole trunks and root crowns), mesofossils (twigs, needles, leaf litter) and microfossils (pollen). The fossil flora provides insight into the local vegetation and the climate of the region. The WDL morphology and the sediment within and surrounding these lenses assist in understanding the ancient river system.

The field site is located in the northwest corner of Banks Island, Northwest Territories, Canada in the Ballast Brook River Valley (Fig. 1). Here a modern river has cut through the mid-Miocene sediment to expose the entire Beaufort Formation and the upper portion of the Ballast Brook Formation. Both formations are characterized by unconsolidated alluvial material and were once considered the same formation (Fyles et al. 1994). Paleobotanical evidence from biostratigraphic studies suggest the Beaufort Formation is late Pliocene whereas Ballast Brook Formation is mid-Miocene in age (Fyles et al. 1994). The unconformity separating these units lies a few meters above a laterally continuous peat layer. This study focuses on how WDL in the Beaufort Formation relate to the paleoenvironment and what information they have archived over time. With the data stored within these deposits our hope is to better understand the local paleoenvironment of deposition and the ever-elusive upland environment.

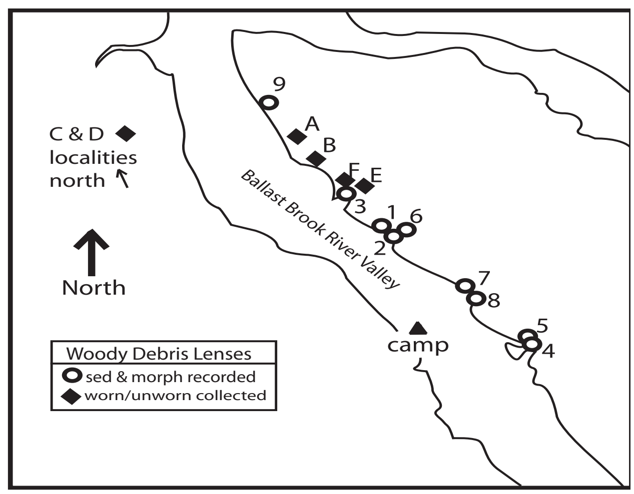

Figure 1. Field map of woody debris lens locations in the Beaufort Formation at the Ballast Brook field area. Lenses C & D are located north of the map area.

BACKGROUND

The Beaufort Formation is a variably thick deposit of unconsolidated sand and silt that was first described on the more northern, Prince Patrick Island by Fyles (1990). The Beaufort Formation extends north from the Banks Island area through most of the western coast of the Canadian Arctic islands. Facies descriptions of the formation indicate deposition in a fluvial river system. An eastern source of the sediments suggests deposition in the basin by westward paleoflow. Two depositional environments in the Beaufort Formation have been described: sandy-braided and gravelly-braided (Fyles et al. 1994).

At my field site at Ballast Brook the Beaufort Formation is up to 80 m thick. Cut and fill structures were found throughout the formation, with channels measuring 2 – 3 m in depth and 5 – 20 m in length (Fyles et al. 1994). The sediment is dominated by silt, sand, gravel and plant debris. Some bedding structures, mainly planar and trough cross-stratification, are present.

The floral remains suggest a coniferous forest similar to extant subartic forests (Fyles et al. 1994) now seen on the present-day Mackenzie River near Inuvik, Northwest Territories, Canada. WDL contain heavy concentrations of wood (articulated pieces alongside water-worn, rounded pieces) and smaller plant material.

FIELD METHODS

Field observations of Beaufort Formation WDL suggest two distinctive types. Of the many WDL, nine lenses were selected (Fig. 1, lenses 1 – 9) for data collection based on their potential to highlight the specific types of lenses observed in the formation. Lenses were measured in their outcrop dimensions by taking a lateral measurement with vertical thickness measurements every 50 cm. Lenses were described in the context of their underlying sediment and vertical variation through measured sections. Notes pertaining to location, morphology, sediment and wood debris were taken for each lens. Wood and sediment samples were collected throughout and below all lenses. For lenses 7 and 8 detailed collection of sediment was taken for future pollen analysis. In addition to the nine lenses recorded for sedimentological and morphological purposes, worn and unworn wood samples were collected from six other lenses (Fig. 1, lenses A – F). Brief notes were taken on lens morphology and surrounding sediment.

Figure 2. Examples of unworn and worn wood quality. 2A: Unworn wood sample. 2B: Worn wood sample.

For lenses 1 – 9 characters such as sediment sequence, type of bedding, degree of taper, symmetry and size of woody debris were selected and scored. The lenses were compared by their characters and then classified according to specific character pairings.

Wood samples from lenses A – F were organized according to lens and a worn/unworn distinction. This distinction was made based the degree of articulation and roundness of fragments (Fig. 2 A&B). Unworn wood (Fig. 2A) was well-articulated with tiny branches still attached to some pieces whereas worn wood was much more rounded, of poorer preservation quality and lacked exterior details of the wood. Ring thickness, fragment circumference, and relative size were recorded for each sample.

RESULTS

Description and classification of lenses

Two types of WDL can be discerned within the Beaufort Formation drawing primarily on the underlying sediment sequence and coarseness of wood debris. "Type A" lenses are defined by a fining upward sediment sequence beneath the lens and medium sized woody debris. Lenses 1 (Fig. 3), 2, 4, and 5 are "Type A" and often overlie planar bedding. "Type A" morphology is relatively symmetrical with all lenses displaying gradual lateral taper. The wood found within "Type A" is well-preserved and of varying sizes. There are often small twigs mixed with logs up to 1 m in length and articulated cones.

Figure 3. Lens 1 on field map (Fig. 1), example of "Type A" lens. Shovel on the left is approximately 1 m in length.

"Type B" lenses 3, 7 (Fig. 4), and 9, are described with having uniform bedding beneath the lens and contain only fine, well-sorted plant material. These lenses are not laterally symmetrical. All "Type B" lenses have internal layering which separates lenses into separate beds that dip approximately 15° - 30° downstream in paleoflow. The layers are defined by centimeter thick beds of very fine silt and sand that run diagonally through the lens. The wood found within "Type B" consists of mainly small, worn and weathered pieces of broken twigs and branches. The pieces are often black and partially decomposed.

The remaining lenses (8&9) are classified under "Type C" or anomalous because these lenses do not display any consistent characteristics that relate to other beds. These lenses have varying types of morphology and debris size. Lens 6, consists of extremely coarse wood and massive bedding beneath. Lens 8 has fine woody debris similar to the debris found in "Type B" but does not have massive bedding beneath it. Instead it has a series of plant debris beds, silty sand, clay and gravel interbedded lenses.

Figure 4. Lens 7 on field map (Fig. 1), example of "Type B" lens. Lens is outlined to emphasis shape. Lens is approximately 0.5 m thick in the middle.

Woody debris

In addition to the description and classification of WDL 1 – 9, I analyzed the worn and unworn woody debris found within lenses A – F. Growth rings were counted and measured in the lab. In Figure 5 individual ring thickness was plotted for each sample according to their lens and worn/unworn distinction. Average ring thickness was also calculated. The results indicate that in general the average ring thickness is larger for unworn wood. Average ring thickness values for each lens and worn/unworn groupings are (in mm): Lens A worn 0.71, unworn 0.68; Lens B worn 0.78, unworn 0.60; Lens C worn 1.04, unworn 0.68; Lens D worn 0.74, unworn 0.64; Lens E worn 0.92, unworn 0.48; and Lens F worn 0.96, unworn 0.59.

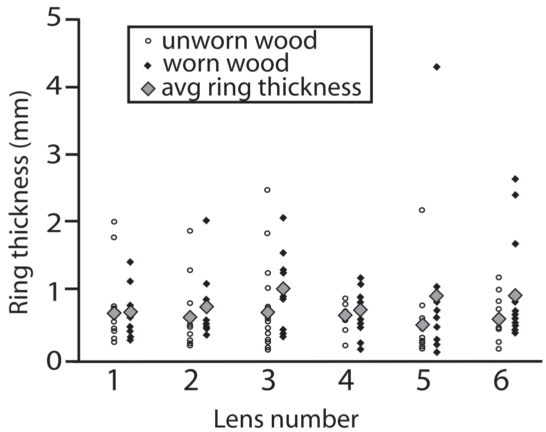

Figure 5. Ring thickness measurements of worn and unworn wood debris within woody debris lenses of the Beaufort Formation.

DISCUSSION

Deposition

Through comparisons with present-day debris jams and their corresponding depositional systems, an interpretation for the deposition processes of the fossil WDL can be inferred. Various present-day debris jam classification schemes have been developed but none of these schemes readily apply to fossil debris jams. Previous classifications included measurement of the parameters of 3D channel morphology and flow rate (Wallerstein 2004) – factors that cannot be directly measured from a fossil debris jam. For this study, coarseness of material, overall morphology, and other internal characteristics were used to describe and classify fossil debris lenses.

Deposition of Beaufort WDL was high in this area because the river system is inferred to be mainly a sand-gravel dominated braided river (Fyles et al. 1994). These systems are typified by numerous bars and shallow channels that may trap floating wood on channel sides, bottom or bars. This is seen in modern examples of these settings; the largest quantities of wood accumulate in the wide, shallow, multi-channel portions of a river (Wyzga 2005, Braudrick 2001). Deposition generally occurs where water is shallower than the depth needed for logs to stay buoyant or where the channel width changes disproportionally to log length (Braudrick 2001). Braudrick (2001) ran flume experiments to discover where deposition occurred and three main deposition locations were found: heads of small islands and bars, locations where flow shallows and the outside perimeter of channel bends.

In this study I applied the three depositional locations described above to the WDL in the Beaufort Formation in order to gain a better understanding of the past depositional techniques that created fossil WDL. "Type A" lenses which contain medium to large pieces of wood, are poorly sorted and randomly oriented were likely deposited in the bend of a river. As a lengthy piece of wood travels around a bend it gets caught on the bank and creates a blockage where other medium and large pieces of wood get caught. This jam acts like a trap for larger pieces but allows the smaller plant material through with the water. This situation can also describe the formation of fining upward sequences beneath the lens. Debris jams often create pools behind them. If the flow of water is obstructed then this causes the deposition of the sediment behind the bar to fill in a fining upward sequence as the immediate area becomes lower and lower in energy. Braudrick (1996) found in a flume experiment that shallowing was associated with wood deposition but it is unsure whether shallowing *causes* wood deposition or if shallowing is actually *caused by* the deposition of wood.

Being composed of only fine plant debris, "Type B" lenses were likely deposited on shallow bars or banks. This is inferred from the lack of large and even medium size pieces of debris. Larger pieces of wood have more momentum as they travel down stream allowing the pieces to move through the friction associated with shallow bar and banks (Braudrick 2001). Since only small pieces of debris, which lack momentum, get caught in these areas we can infer "Type B" lenses were deposited in this fashion. Bars and banks do not necessarily have a sediment sequence such as fining upward or downward associated with them and the same is true for the sediments beneath "Type B."

The anomalous lenses in this study can also be explained by this model. In lens 6 it can be inferred the large, 50 cm tree trunk at the base of this lens was what started the accumulation of more debris. Lens 8 is uniform and symmetrical in shape, contains fine, disaggregated plant material and is thought to be a channel fill. There is a coarse pebbly layer directly below this lens while a number of horizontally continuous fine plant debris layers are above this lens. This indicates the gradual filling of the channel first with the pebble layer, then with an abundance of fine silt, sand and plant debris and finally the channel is full and the remaining water and debris spread out horizontally on top.

Paleoenvironmental Archives

WDL possibly provides paleoenvironmental information about the vegetation present in upland environments. Worn wood, because of its rounded appearance, is considered allochthonous. The distance of wood transport depends largely on channel morphology (Wyzaga 2005) and channel roughness (Braudback 2001) but it is not uncommon for wood to travel a significant distance. Likewise, because unworn wood has articulated external features it is considered autochthonous and thought to not have traveled far from its original source. Since trees grow more quickly in warmer (often upland) environments we can infer trees would produce thicker growth rings than the forest stands further downstream. The results of this study indicate worn wood has, on average, larger ring thickness. This supports an allochthonous origin and indicates worn wood's source may be an upland environment. Though worn wood may only be indicating local abrasion instead of distant transport – the fact that worn wood has thicker rings on average assists in the conclusion of distant transport. It is also important to consider the possible affects of water availability on tree ring thickness. For example, presently in Canada's Mackenzie Delta the trees growing on the river bottom grow faster because the soils are thinner, thaw quicker, and allow the trees greater water availability. Accordingly, the trees grown upland in the permafrost have less water available and thus smaller tree rings. While this situation proposes the opposite interpretation on ring thickness, a temperature difference due to a cold air drainage affect may explain warmer upland and cooler lowland environments. Temperature inversions can occur causing the cold dense air to drain to low elevations allowing the warmer air to radiate upward, warming the upland environment. Cold air drainage may allow trees to grow faster upland in a warmer environment. More specific wood identification for worn and unworn wood samples could be undertaken to gain insight into upland forest stands. If worn and unworn wood samples indicate distinctive communities this then suggests different growth locations.

The addition of the wood to the river system may be explained by eroding stream banks. Wallerstein (2004) found in his study of unstable, degrading, sand-bed rivers that most wood entered the river because of failure of unstable channel banks. This links the introduction of large woody debris (the number of jams and volume of wood debris) to channel evolution (Wallerstein 2004). This could mean the Beaufort Formation is recording (since the formation consists of sand facies) a degrading river system of eroding banks which cause the channel sides to fail thereby adding a large amount of large wood debris to the river and creating debris jams within the channel.

Questions remain as to how these lenses were covered over and preserved so well. This may be explained by channel avulsion, where an unstable system may have resulted in shifted stream channels leaving the debris jam in an empty channel. Later the debris jam could have been covered over by floodplain deposits.

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