Natural Disturbance History in the ICHwk3: Fire and the Prehistoric Record of Slope Processes

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ABSTRACT

Increased public interest in the management and conservation of the northern Interior Cedar-Hemlock biogeoclimatic zone requires a better understanding of disturbance regimes, and in particular, the role of infrequent but severe stand-destroying fires. In the Rocky Mountain Trench, geomorphic processes have created a particularly rich record of Holocene fires in the form of charcoal buried in colluvial and alluvial fans derived from dissected glaciolacustrine terraces in the lower Morkill River valley of the Robson Valley Forest District.

Radiocarbon dating of these charred wood and forest floor materials has yielded dates up to 8500 BP (before present), indicating that wildfires have been an important disturbance agent throughout the Holocene, with recurrence intervals of perhaps 500 -1000 years.

Complex soil profiles in these colluvial and alluvial fan settings frequently included stacked multiple charcoal-bearing strata, which were usually laterally discontinuous, with overlapping age ranges. Observation of modern fire-triggered slope failures suggested mechanisms for formation of such deposits, and have provided criteria for distinguishing in situ from transported charred horizons.

In these glaciolacustrine landscapes, the lower-energy environment of colluvial toeslopes appears to be more suitable than alluvial fans for creating and preserving such records. Similar dissected glaciolacustrine landforms occur in several other major valleys in the western slopes of the Rocky Mountains, so this technique has potential for much wider application.

Land managers need to recognize that wildfire has been an important disturbance agent in this portion of the ICHwk3 throughout postglacial time. Therefore, silviculturists should not exclude prescribed fire as a management tool, and managers of protected areas should consider this historical perspective when developing policies for responding to wildfires.

Keywords: disturbance processes, fire, radiocarbon dating, charcoal, Interior Cedar-Hemlock zone, glaciolacustrine, colluvium, alluvial fans, Holocene
1. INTRODUCTION

1.1 Rationale:

The approach of using natural disturbance regimes to guide the spatial and temporal patterns of forest management has become increasingly influential, but requires both stand- and landscape-level understanding of disturbance processes. For landscapes in boreal and sub-boreal forest types, much of the needed information can be derived from forest inventories and forest cover mapping (e.g. DeLong and Tanner, 1996). In forest types with infrequent stand-initiating events, defined as Natural Disturbance Type (NDT) 1 (MoF-MELP, 1995), stand structures, tree rings, and landscape patterns may not provide a complete enough historical perspective – ring sequences are often incomplete in old trees of some species, and small-scale turnover through gap-driven processes may obscure the imprint of rare but severe events.

These and other limitations apply very much to the disturbance history of the wetter subzones of the Interior Cedar-Hemlock (ICH) biogeoclimatic zone in the Rocky Mountain Trench – the largest and likely oldest trees on many sites are western redcedars, which are almost always hollow or rotten, and there have been no previous palaeoenvironmental studies of Holocene vegetation history using methods such as pollen analysis of lake sediments.

Nevertheless, severe stand-destroying fires do occur in these subzones, and understanding their frequency, magnitude and effects is important for managers of both the timber harvesting landbase and protected areas. For example, recent practice in the ICH, reflecting province-wide trends, has been to reduce greatly the amount of broadcast burning after harvest. But any decision to exclude or retain such an important part of the silviculturist’s toolkit needs to be based on some understanding of the historical role of fire in these ecosystems. Similarly, with the designation of new protected areas in the northern ICH, land managers need to understand the historical role of fire as a part of these ecosystems.

1.2 Status of knowledge prior to study:

When the pilot phase of this study began in 1999 and 2000, only limited work had been done on the disturbance regimes of the ICH or its approximate equivalents in the U.S. Pacific Northwest. The wetter variants of the ICH of BC are “unique in the world and really should be considered as inland rainforests” (Arsenault, 1998), with considerable topographically-controlled variation in fire return intervals. For analogous, but somewhat drier ecosystems in northern Idaho, Alaback et al. (2000) expressed similar views: “the moist forests on the west slopes of the Rocky Mountains are unique from both a regional and continental perspective”. Unlike the more abundant coastal counterparts of these ecosystems, the advent of a significant ecological research effort in the wetter subzones of the northern ICH is very recent. While the science of coastal temperate rainforests has advanced to the point where broad syntheses have been published (e.g. Lawford et al. 1996), the first symposium on the northern Wet Belt of BC occurred only in 1997 (Jull et
al., 1998) and emphasized the tremendous knowledge gaps in almost every aspect of the ecology and management of the wetter ICH.

The ICHwk3 and associated subzones/variants are considered to belong to Natural Disturbance Type (NDT) 1, defined by the Biodiversity Guidebook (MoF-MELP, 1995) as having “rare stand-initiating events”, with return intervals of 250 years. As Arsenault’s initial work in the wetter ICH variants of the southern Interior suggests, this single category likely includes a large range of disturbance return intervals, with some ecosystems almost completely lacking evidence of catastrophic fires. Closer to our study area, the adjacent wet and cool subzones of the Sub-Boreal Spruce and Engelmann Spruce-Subalpine Fir biogeoclimatic zones on the western slopes of the Rockies may have fire cycles as long as 560-700 years (Vasbinder et al., 1998).

The research literature on long-term fire regimes in forested landscapes has mostly involved analyses of charcoal particles isolated from radiocarbon-dated cores of lake sediments and bogs. This technique has generated a rich literature, as recently synthesized by Clark et al. (1997) and a special issue of Palaeogeography, Palaeoclimatology, Palaeontology (v. 164). Although we have identified lakes and ponds suitable for this purpose in the Rocky Mountain Trench in and near the ICHwk3, no sediment-based charcoal (or pollen) studies had been conducted in the northern ICH as of December 2000, according to authorities in both BC and Alberta (pers. comm. from R. Hebda (Royal BC Museum), A. Beaudoin (Alberta Provincial Museum)).

Recent studies in wet coastal forests in southwestern BC have successfully used accelerator mass spectrometry (AMS) radiocarbon dating of charcoal from forest humus layers to construct fire histories (Gavin, 2001; Gavin et al., 2003; Hallett et al., 2003). Scandinavian studies have shown that the presence of charcoal in forest floors is a reliable indicator of local fire influence (Ohlson and Tryterud, 2000). The pilot study on which this proposal was based initially sought to find similar evidence in the forest floors at ICH sites in the Rocky Mountain Trench between McBride and Prince George. However, we were also aware of other studies in which deeper deposits of charcoal, associated with buried surfaces in alluvial fans, had been used to reconstruct watershed fire chronologies (Meyer et al., 1992; Meyer et al., 1995, 2001; Meyer and Wells, 1997). Since the inception of this study, at least two additional U.S. studies have been published which used similar methods for reconstructing watershed impacts of historical fires (Meyer et al., 2001; Elliott and Parker, 2001). (Although Dormaar and Lutwick (1975) had much earlier recognized similar charcoal horizons in alluvial fans in Banff National Park, they did not use these deposits as a tool for constructing fire chronologies.) In a British Columbia study of early postglacial sedimentation processes, Lian and Hickin (1996) noted the occurrence of early Holocene charcoal in alluvial fans in the lower Seymour Valley of the Lower Mainland, and speculated on the effect of climatic change on fire frequency and resulting sedimentation rates.

The landmark study by Meyer et al. (1992, 1995) of alluvial fans and stream terraces in Yellowstone National Park marked the first time that a single study had so elegantly married the interpretation of modern slope and fluvial processes – erosion and sedimentation after the severe 1988 wildfires – to the study of prehistoric fire-related
deposits, anchored by a large suite of AMS dates. Meyer concluded that fire-related debris flows and other sediments comprised approximately 30% of the volume of Holocene alluvial fans in his study area, with much of the remaining volume of likely, but unproven, fire origin. (Two other more recent studies appear to have used somewhat similar methods (cited by Figueiral and Mosbrugger (2000)), but these were conducted in the tropics.) Although other studies (Bierman et al., 1997; Anderson et al., 2000) have used radiocarbon-dated organic materials preserved in temperate zone alluvial fans to document environmental change, and Carcaill et al. (2001) has used AMS-dated charcoal to study turbation processes in subalpine soils, the Yellowstone studies were the first to focus on fire history.

1.3 Objectives:

As stated in our original application, our main objective is to determine whether severe fires have been a recurring influence on soils and slope processes in the ICHwk3 of the Robson Valley Forest District during Holocene time. A subsidiary objective was to examine the temporal distribution of such events, in order to estimate return intervals and detect any long-term trends. We also recognize that landform characteristics influence the likelihood that certain types of fire-related evidence will be created and preserved, so a third objective is to identify this influence on the utility of our methodology.

1.4 Project history:

While assisting Mike Jull (then a UNBC Research Associate) in 1999 with ecosystem mapping and characterization of soils at three silviculture research sites in the ICHwk3 and vk2 (FRBC Project OP96081-RE), Paul Sanborn encountered occurrences of buried charcoal in alluvial fans at the East Twin and Minnow Creek study sites (Figure 1). (Earlier discussions with Ken Lertzman (SFU) had made us aware of the potential of using soil charcoal in reconstructing fire histories in wet, NDT1 forests, so we were keeping our eyes open.) Samples of these materials were sent for AMS radiocarbon dating at the University of Arizona, and yielded ages ranging from 363 ± 73 to 4,735 ± 50 BP. Simultaneously, we were able to observe the after-effects of the severe 1998 wildfire in the adjacent ICHmm subzone of the Dore River valley, and noted the post-fire deposition of fresh sediments on alluvial fans.

In 2000, we conducted additional reconnaissance field work in all accessible major drainages of the ICHwk3 in the Robson Valley Forest District (Goat R., West Twin Ck, East Twin Ck., Fleet Ck., Morkill R.) (Figure 1), as well the lower McKale R. valley in the ICHmm. Radiocarbon ages of charcoal from these sites ranged up to 7,467 ± 57 BP. From previous field experience and an earlier study (Froese and Cruden, 2001), we were aware of the distinctive geomorphology of the Morkill River valley (Figures 2 and 3) and gave it particular attention, resulting in the discovery of several sites with multiple charcoal layers in slope deposits and alluvial fans accumulated below the deeply dissected silty glaciolacustrine terraces.
Figure 1. Study site locations in the upper Fraser River watershed.
Figure 2. Typical air photo view of deeply dissected glaciolacustrine sediments in the Morkill River valley (approximate scale 1:40,000). Local relief created by gullies is 100-150 m.

Figure 3. Oblique helicopter view (June 2002) of dissected glaciolacustrine sediments similar to those shown in Figure 2.
During the FRBC-funded portion of this project (2001-2002), we decided in June 2001 to concentrate our efforts on the ICHwk3 portion of the lower Morkill River valley, rather than to include additional watersheds during any subsequent second year (i.e. 2002-03). As a result of this successful field work, by July 2001 we had collected enough datable material to use up all of our proposed radiocarbon dating budget for both years of the project.

2. METHODS

2.1 Research methodology & sites:

As a result of our decision to focus on the Morkill River area, our 2001 and 2002 field work concentrated on the ICH portion of the lower 30 km of this valley, including the lower 1 km of its tributary, Forgetmenot Creek. Almost all sampling sites were located within 200 m of the main Forest Service roads. We systematically examined all likely areas of toeslope colluvium and alluvial fans deposited below the steep scarp faces of the deeply dissected glaciolacustrine terraces. We were able to decide quickly whether a site had potential by simply hand-augering to approximately 1 m depth and looking for any indications of buried organic or charcoal deposits. Where available, we also inspected all accessible roadcuts, failure scarps and gully side-walls, but with the augering method, we were able to explore a much larger area more quickly and thoroughly. Our sampling areas were seldom more than 1 km apart, and by early July 2001, we had identified approximately 25 sites. Additional field work in mid-June 2002 found a further 7 sites.

Because of the sensitivity of the AMS radiocarbon dating method, which can work with charcoal samples of 5 mg or less, we were able to date materials in which the charred material consisted of very finely divided particles.

2.2 Data collected:

Our primary data consist of field descriptions of soil profiles and excavations at over 30 sites in the lower Morkill valley. We described the depth, continuity, colour and other characteristics of charcoal-containing layers, and took multiple photographs of all sampled layers and sections. This descriptive information has been recorded in the format used by the NSF Arizona Accelerator Facility for all samples submitted for radiocarbon dating.

We also documented recent fire-related slope instability at sites disturbed by both wildfire and escaped slashburns in the Morkill valley in the 1990’s. We paid particular attention to a recent slope failure at km 12.1 on the Morkill FSR, and revisited this site to examine deposits that had accumulated or been modified since our initial visit in June 2001.

To gain additional perspective, we did a helicopter flight over our study area on June 11, 2002, and obtained over 100 photographs of the Morkill valley and adjacent areas.
2.3 Data analysis methods:

At this stage, our approach is primarily descriptive, because we are still trying to understand the mechanisms responsible for formation of the complex soil profiles with multiple charcoal layers that we have observed in the lower Morkill valley. In particular, the clustering of multiple dates observed in some sections may be a result of the failure mechanisms in these glaciolacustrine deposits – we are developing field recognition criteria for separating charcoal layers that may not represent individual fire events.

Innovative aspects:

2.4 Innovative aspects

This study is the first attempt in Canada to reconstruct fire history using radiocarbon-dated charcoal derived from below the surface organic layers of soil profiles and colluvial and/or alluvial fan sediments, and as noted above, is an approach that has had few applications elsewhere. The particular attributes of our Morkill study area and the richness of the fire-derived sedimentation record are distinctive features of our study. In addition, through collaboration with project partners who have joined our team since inception of this project, we will be directly addressing significant information gaps on the Holocene vegetation history of the ICH and the characteristics and dynamics of charcoal in the soil carbon cycle.
3. RESEARCH ACTIVITIES

3.1 Field activities:

In June and July 2001, and in June 2002, we re-examined the areas affected by the 1998 Dore River fire, to observe any additional slope instability and alluvial fan sedimentation that had occurred since 2000. Our clear impression was that little additional activity has occurred since our visits in 1999 and 2000 (Figures 4-6), and given the great differences in geology and soil parent materials, we feel that the Dore fire area has limited value as an analogue to our current primary study area in the lower Morkill River valley. To understand what we are seeing in the prehistoric record of fire-triggered sedimentation in the Morkill, it therefore is much more appropriate to examine areas with similarly erodible glaciolacustrine materials.

Figure 4. July, 1999, view of slope failures and alluvial fan deposition following the August, 1998, Dore River fire.

Figure 5. Fresh sediment deposits (May, 2000) at toe of alluvial fan (lower right, Figure 4).
We returned to the active slope failure at km 12.1 on the Morkill Forest Service Road in order re-examine the deposits initially documented in 2001. This site was logged in the early 1990’s and subsequently broadcast burned, but the conspicuous failure scar does not appear in May 1995 air photographs. We observed several features at this site that provided considerable insight into the mode of formation of some of the buried features that we have observed in complex colluvial / alluvial fan deposits elsewhere in the Morkill valley.

We noted two distinct zones and modes of deposition at this site (Figure 7). At the toe of the failure scar (Figure 7a, b, c), there was an accumulation of blocks of soil, approximately 1-2 m in diameter and 50 cm thick, held together by tree roots. These blocks had come to rest in a variety of positions, and it was easy to visualize this as the mode by which multiple charcoal buried layers, all of similar age, could become stacked up in these colluvial deposits. Farther downslope, there was a transition to an alluvial fan environment where approximately 20 cm of water-transported sand and silt had buried the pre-existing soil.

Excavation in the colluvium at the base of this failure (Figures 7, 8) revealed a complex accumulation of multiple charcoal-bearing layers, with ages of between 3000 and 4000 BP, beneath a much younger layer (402 BP) that likely marked the pre-1995 soil surface. The older multiple layers probably accumulated after a single previous fire-triggered slope failure, and the spread of radiocarbon dates reflects the in-built age phenomenon in soil charcoal documented by Gavin (2000, 2001). The example also illustrates the difficulty in trying to reconstruct fire chronologies from this type of evidence, and suggests clear limits on our ability to identify accurately individual events.
Figure 7. Recent (post-1995) slope failure and resulting deposition modes, km 12.1, Morkill Forest Service Road. (The red circle at the base of the failure scar indicates the location of the excavation illustrated in Figure 8.)

*Modern processes: active post-fire slope failures (Morkill R.)*
Figure 8. Multiple charcoal-containing layers with similar radiocarbon ages in colluvial deposit at km 12.1, Morkill Forest Service Road.

Ambiguities in the soil charcoal record:

- 402 ± 38 BP
- 3,346 ± 42 BP
- 3,211 ± 41 BP
- 3,831 ± 51 BP
- 4,124 ± 81 BP
- 3,617 ± 42 BP
Our helicopter overflight allowed us to get a good view of recent slope failures triggered by the 1992 Cush fire, north of the Morkill River and upstream of its confluence with Foregetmenot Creek. We observed numerous failures similar to those at km 12.1, and it was noteworthy that these had occurred both where salvage logging had been done, as well as where standing snags had been left (Figure 9). We do not know how long after the fire these failures had occurred, but our observations elsewhere suggested that a lag of perhaps 5 years was needed for loss of residual root strength.

Figure 9. Slope failures in glaciolacustrine deposits affected by the 1992 Cush fire, Morkill River valley.
Although the charcoal samples recovered before 2002 were more than sufficient to use up our available funds for radiocarbon dating, our June 2002 field work yielded additional sites that verified our earlier interpretations of the types of depositional settings where preservation of these materials was favoured. In addition to those sites listed in the 2001-02 annual report to FRBC, we also recovered buried charcoal from colluvial or alluvial fan deposits at kms 8.4, 9.4, 13.4, 14.6, 18.1, 18.2, and 28.5 on the Morkill Forest Service Road (Figures 10-12).

Figure 10. Buried charcoal layers (numbered) in colluvial deposits at the scarp base of dissected glaciolacustrine terrace at km 8.4, Morkill Forest Service Road.
Figure 11. Buried charcoal layers (numbered) in fluvial deposits partially infilling a gully in the glaciolacustrine terrace at km 13.4, Morkill Forest Service Road.
Figure 12. Buried charcoal layers (numbered) in alluvial fan deposits exposed by roadcut at km 18.1, Morkill Forest Service Road.
3.2 Participation of partners

The four original team members carried out their roles and responsibilities as originally planned in the project application. Paul Sanborn and Marten Geertsema (Ministry of Forests) undertook the bulk of the final field work in mid-June, 2002, assisted by two Ministry of Forests summer students. Tim Jull (University of Arizona) conducted the AMS radiocarbon dating, and Brad Hawkes (Canadian Forest Service) provided continuing advice on interpretation of fire regimes.

The Robson Valley Forest District has been key partner in this work since the pilot phase of this project in 1999 and 2000, and with the closing of the District office and its amalgamation with Clearwater Forest District, we are uncertain as to future working relationships during the follow-up phase of this project.

We have continued to work with two new collaborators, recruited in 2001, whose activities have been funded outside this project: Dr. Richard Hebda (paleobotanist – Royal BC Museum / Univ. of Victoria) and Dr. Caroline Preston (soil organic chemist – Canadian Forest Service, Pacific Forestry Centre).

Since assisting Dr. Hebda in July 2001 with coring a small lake near km 4.5 on the Morkill Forest Service Road, we have obtained basal radiocarbon dates of approximately 9500 BP, indicating almost all of postglacial time will be encompassed by this core. Macrofossils sampled from a peat deposit at Minnow Creek, approximately half-way between McBride and the Morkill River also exceeded 8000 BP. (These dates were funded from the separate research grant provided by UNBC to Paul Sanborn in early 2001.)

Dr. Hebda intends to conduct a full pollen analysis of the lake sediment core, as well as examine the long-term fluctuations in charcoal particulate input – a proxy indicator of local fire activity. Taken together, these lines of evidence will provide crucial complementary data for the more intermittent record of fire effects provided by this study. To fund this related work, Hebda, Sanborn, and Hawkes submitted a proposal entitled “Sensitivity and potential response of the Interior Cedar Hemlock (ICH) forest zone of British Columbia to climate change" to the federal Climate Change Action Fund in early February, and are awaiting a final decision as of this date. (As a direct result of the local interest in our ICH fire history research, the Hebda proposal received a significant pledge of matching support from a McBride-based forest licensee, TRC Cedar.)

Dr. Preston, a recognized authority on the chemistry of soil organic matter, is currently involved in international collaborative research on the characteristics and fate of charcoal in forest soils. This topic is an area of considerable research activity as a result of the global concern over the possible role of forests and soils as carbon sinks. We assisted Dr. Preston in obtaining additional charcoal samples from selected sites in the Morkill, as well as areas affected the 1998 Dore River fire. Her data for these sites were presented at in a talk at the annual meeting of Soil Science Society of America in Indianapolis in November 2002, along with findings from similar analyses of charcoals collected from the boreal forest in central Canada and Siberia (see Appendix 1).
3.3 Key Advances:

1. We now have clear evidence, in the form of more than 160 soil charcoal samples obtained over the past four field seasons, that fire has been an important factor in ecosystem and watershed processes in our study area for most of the Holocene. Of course, pending the completion of parallel palaeobotanical studies by our collaborator, Dr. Hebda, we are unable to state how long plant communities similar to those of the modern ICH have existed in this area.

2. We have demonstrated that colluvial and alluvial fan deposits derived from the reworking of medium-textured glaciolacustrine materials provide an ideal setting for the creation and preservation of a rich record of Holocene fires. Unlike earlier studies in other environments, such as Yellowstone National Park (e.g. Meyer et al., 1992; 1995), we found that alluvial fans were not always the richest repositories for fire-related deposits – the lower-energy depositional setting of toeslope colluvial sites generally preserved evidence of a larger number of events. This finding suggests that there is great potential to extend this type of investigation to several other valleys with similar geomorphic settings along the western slopes of the Rocky Mountains (e.g. McGregor River, Herrick Creek, Torpy River, Parsnip River, Ospika River.)

3. Our charcoal radiocarbon dates from the lower Morkill River valley appear to indicate fire return intervals of approximately 500-1000 years throughout the Holocene. When complementary data are available from charcoal particulate analysis of Dr. Hebda’s lake sediment core from the Morkill, we will be able to construct a unique synthesis of fire history and long-term vegetation change in a poorly-understood area of B.C.

4. Our observations of recent slope failures considerably clarify the interpretation of complex and discontinuous sequences of buried charcoal-bearing surfaces in older toeslope colluvial deposits derived from glaciolacustrine sediments. We found that formation of such deposits involves accumulation of root-reinforced masses of surface soil materials, which may come to rest in a variety of positions, and which are complexly interbedded with water-transported materials. Hence, it is possible for several distinct but laterally discontinuous charred surface layers to occur in the same profile, but all representing deposition triggered by the same fire. This likely accounts for the overlapping or clustering of the radiocarbon ages of stacked multiple charcoal layers observed in some sections in the Morkill, and provides an additional inherent complexity in their interpretation, beyond those noted for surface or forest floor charcoal deposits by Gavin (2000).

5. Through our assistance to collaborators, and the links with other local partners that have been strengthened by this project, we have contributed to two complementary studies that will considerably enhance the impact of this study. (a) Dr. Hebda’s successful coring of a lake in the lower Morkill valley and recovery of datable peat and macrofossils from the Minnow Creek research site have the potential to provide an important missing piece of the story of Holocene vegetation history in the ICHwk3 – part of a globally rare ecosystem, inland temperate rainforests. (b) Dr. Preston’s sampling and characterization of charcoal from our Morkill study area has contributed to an international research initiative on the role of black
carbon in the global C cycle, and initial results have already been presented at two international conferences.

6. As a by-product, we have contributed to a better understanding of the early Holocene geomorphic history of the Morkill River valley, by providing radiocarbon dates that constrain the timing of major downcutting of the thick glaciolacustrine fill – our evidence suggests that this activity was very rapid and had largely run its course by about 8,500 BP.

4. EXTENSION ACTIVITIES

During 2002-03, we made oral or field trip presentations on this research at 4 conferences and 2 post-secondary institutions; published abstracts and trip field guides are in the Appendix.

1. Canadian Society of Soil Science / Canadian Geophysical Union, Banff, May 19-23

   Oral presentation to a special session on Forest Soil Carbon Cycling, with an audience of approximately 100 soil scientists and forestry researchers.

2. 4th International Workshop on Disturbance Dynamics in Boreal Forests, mid-conference field trip, August 2002

   Approximately 200 conference delegates visited our sampling site at km 1.8 on the Morkill Forest Service Road, where Paul Sanborn gave an overview of the project and showed examples of dated buried charcoal deposits in an alluvial fan exposed by a roadcut.

3. Research Seminar, Northwest Community College, Smithers, October 25, 2002

   Oral presentation to an audience of approximately 30 forestry and earth science professionals from the Smithers area.

4. Geological Society of America annual meeting, Denver, Colorado, October 29, 2002

   Oral presentation to approximately 200 earth scientists, as part of a day-long theme session on “Geomorphic Effects of Wildfires”.


   As a result of her joint field work with us in July, 2001. Dr. Caroline Preston of the Pacific Forestry Centre, Canadian Forest Service, included chemical data obtained for charcoal samples from our study area in an oral presentation.

6. Guest lecture on geomorphic effects of disturbance processes to UNBC graduate course, NREM 798: Natural Disturbance Processes.
5. SUMMARY AND CONCLUSIONS

Our 2001 and 2002 field work has justified our confidence that the ICHwk3 portion of the lower Morkill River valley would be a fruitful area for seeking soil evidence of Holocene fire-related disturbances. Our collection of over 160 datable charcoal samples, combined with observations of modern fire-related slope processes, has given us a much deeper understanding of the historical role of fire in these ecosystems, and on some of the limitations to interpreting this record. Through support provided to our new research collaborators (at no cost to the FII-funded portion of our budget), we have facilitated significant complementary work on vegetation history of the ICH and the role of black carbon (charcoal) in the soil carbon cycle.

Our work underscores the distinctiveness of the northern, wetter portions of the ICH in the Rocky Mountain Trench. Despite some similarities with the Coastal Western Hemlock zone in terms of dominant tree species (western hemlock, western redcedar), our study area appears to have been much more continental in its historical disturbance regime, with much more of a role for fire – fires severe enough to create erosion and sedimentation events recorded in colluvial and alluvial fan deposits.

There are clear implications for managers of landscapes in the northern part of the Rocky Mountain Trench in the Robson Valley Forest District: (1) fire is a part of the historical functioning of these ecosystems, and therefore should not be excluded from the array of site preparation methods available to silviculturists, and (2) in management of protected areas, fire should be viewed as part of the disturbance regime, and subject to other constraints, policies for fire management should recognize that there may be ecosystem attributes which in fact reflect legacies of past fire disturbances. Further research will be needed to identify those attributes and to design appropriate fire management policies that will permit their retention in both protected areas and the actively managed harvesting landbase.
REFERENCES


APPENDIX: Abstracts for Conference Presentations

*Canadian Society of Soil Science / Canadian Geophysical Union joint meeting, Banff, Alberta (May 19-23, 2002)*

**Soil Charcoal Evidence for Holocene Fire History in the Interior Cedar-Hemlock Zone, Rocky Mountain Trench, British Columbia**

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Understanding natural disturbance history can assist land managers in choosing forestry practices that may be more likely to maintain site productivity and biodiversity. In the wet, cold Interior Cedar-Hemlock (ICH) zone of east-central British Columbia, stand-destroying fires are rare, and forest disturbance history is difficult to reconstruct with dendrochronological methods. In this mountainous terrain, radiocarbon dating of soil charcoal created by past fires, and preserved by geomorphic processes, provides an alternative approach.

In a portion of the ICH zone in the upper Fraser River watershed, we have collected over 140 samples of charcoal-rich horizons from alluvial fans, and beneath landslides and other colluvial deposits. AMS radiocarbon ages range up to 8500 BP, suggesting that fire has been an important disturbance agent in this zone throughout the Holocene.

Sites with multiple buried charcoal layers are particularly abundant in colluvial and fluvial materials deposited downslope from dissected silty glaciolacustrine terraces in the lower Morkill River valley, 130 km east of Prince George. The wet climate and extreme erodibility of these terraces favours both creation and preservation of a rich record of datable charred organic materials. Observation of modern post-fire erosion and slope failures has suggested possible mechanisms for the deposition of multiple, laterally discontinuous charcoal-rich horizons. Such processes limit the ability of such soil charcoal deposits to provide a high-resolution record of past fires.

Complementary studies in the Morkill valley and adjacent ICH watersheds are reconstructing Holocene vegetation and fire history through pollen studies of lake sediments and peats, and are examining the chemical properties of black carbon in forest soils.
The cool, wet Interior Cedar-Hemlock zone in the Rocky Mountains of east-central British Columbia, Canada, has a natural disturbance regime with intermittent but severe wildfires that can have significant geomorphic effects. AMS 14C dating of charcoal in colluvium and alluvial fans has been used to reconstruct the Holocene history of wildfires in the lower Mokelumne River valley, a headwaters tributary of the Fraser River.

Early Holocene deposition of thick (>100 m) silt and sandy glaciolacustrine deposits in the Mokelumne River valley created deeply gullied terraces that are vulnerable to erosion and mass wasting when these highly erodible materials are exposed by severe wildfires. This geomorphic setting, combined with a wet climate, favours both creation and preservation of a rich record of datable charcoal. Excavations and natural exposures have yielded more than 160 samples of charcoal from 20 sites, with AMS 14C dates ranging from modern to 8500 BP. Palaeoecological and apparent fire-reddened horizons, with or without associated charcoal, are also common at these sites.

Individual sections in upslope colluvium can contain >20 distinct but laterally discontinuous charcoal-rich horizons. Clustering of AMS 14C dates at such sites could indicate that a single wildfire triggered multiple depositional events. However, observations of modern post-fire erosion and slope failures suggest that such sequences of multiple banded charcoal layers can also form by rapid accumulation of approximately 0.5-m-thick blocks of surface soil, held together by the forest root mat. Such deposits at the base of steep glaciolacustrine terrace scarps often merge laterally downward into alluvial fans that usually contain many younger banded palaeosols and charcoal layers. Both depositional settings have inherent, but differing, limitations as repositories of Holocene wildfire history.

Complementary studies of charcoal age and abundance in lake sediments are needed to help refine this historical record, but the radiocarbon dates suggest that major fire-related erosion and mass wasting events in this landscape occurred at approximately 500 to 1000-year intervals throughout the Holocene.

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Preston*, C.M., Czimczik, C.I., Schmidt, M., Bhatti, J.S., Sanborn, P., Schulze, E.-D. Characterization of black (pyrogenic) carbon in forest soil organic matter

Forest fires, especially boreal wildfires, generate pyrogenic carbon (also called char or black carbon, BC) that may contribute to the very stable soil carbon pool. Current BC research includes analytical methodology, ecological function, and quantification of stocks and fluxes, but there is little direct characterization or quantification of BC generated in forest fires and the effects of weathering and/or burial. Solid-state C-13 NMR provides a fingerprint of total sample carbon, but the high aromaticity of BC requires high-speed spinning and quantitative Bloch decay acquisition in addition to normal CP. We have characterized BC samples from a range of substrates, forest ecosystems (British Columbia Rocky Mountain Trench, the Canadian Boreal Forest Transect Case Study in Saskatchewan and Manitoba, and central Siberia), and ages from a few days to >1000 years of burial or incorporation into soil fractions. Laboratory and field char samples appear to have a structure of small clusters of fused aromatic rings, rather than the larger domains in soot or graphite. We also compared conversion of forest floor to BC in a Siberian wildfire; by NMR and by a more selective chemical method.