Final Report on Seed Project:

Plant-Derived Opal as a Soil Indicator of Vegetation Change in Response to Prescribed Burning

Project M-K-2001-2002-81

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Executive Summary

We examined the concentration and types of plant-derived silica particles (phytoliths) in surface soils and reference grass tissues from representative sites in the upper Sikanni Chief River and Nevis Creek watersheds of the Muskwa-Kechika Management Area. These silt-sized particles passively accumulate in the soil when aboveground tissues die and decompose. Grasses tend to be much more prolific producers of phytoliths than most other plant taxa, so our main objective was to determine if phytoliths provide a means of distinguishing long-established natural grasslands from those created by recent prescribed burning.

Although the two forest sites examined did have the expected low concentrations of phytoliths in surface soils, values for grasslands and mixed grass-shrub communities were quite variable, making it difficult to use such evidence in support of our primary objective. In this dynamic mountain environement, geomorphic processes such as erosion and soil creep may remove or disrupt the surface soil horizons in which phytoliths are normally most abundant.

There still remains considerable potential to use phytoliths in studies of past environmental conditions. Future phytolith research in the M-K and adjacent areas should focus on more detailed characterization of plant reference material and examination of phytolith assemblages in depositional settings, such as buried soils in alluvial fans.

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1. Introduction

As noted in our original application for this Seed Project, prescribed habitat burning has altered the landscape pattern of plant communities in many parts of the Muskwa-Kechika Management Area. Future planning and management activities aimed at protection and/or restoration of wilderness conditions could benefit from improved knowledge of the original distribution of plant communities prior to the advent of this degree of human intervention.

Frequent burning in boreal and subalpine environments will favour grasses, herbs, and shrubs at the expense of coniferous forest. Reconstruction of past vegetation patterns, where recent alteration of fire regimes has shifted the boundaries between forest and non-forested plant communities, requires a site-specific tool that can indicate the relative long-term predominance of these two broad vegetation conditions. Previous research in Alberta (Dormaar and Lutwick, 1969; Lutwick and Johnston, 1969; Sanborn and Pawluk, 1983), Oregon (Norgren, 1973; Witty and Knox, 1964), and the U.S. midwest (Beavers and Stephen, 1958) demonstrates the value of plant-derived opaline silica, in the form of silt-sized *phytoliths*, as a vegetation history indicator. Grasses accumulate amorphous silica in their aboveground tissues to a much greater extent than most other plant groups, and contain distinctive phytolith morphological types. These persistent particles accrete in surface soils, providing a useful index of the long-term degree of grass occupancy of a site.

Before undertaking a large-scale examination of phytoliths in soils of the Muskwa-Kechika Management Area, it is important to have a preliminary understanding of the variation in their amounts and types across a range of sites and plant communities, both with and without a history of prescribed burning. An important consideration is geomorphic stability – in mountainous landscapes, erosion and deposition on slopes can remove or alter the surface soil horizons that tend to be richest in phytoliths. Such processes could confound the interpretation of vegetation history from phytolith distribution patterns.

Beyond simple estimation phytolith content in surface soils to give a proxy measurement of past grassland occupancy, the assemblage of phytolith forms in a soil may yield taxonomically useful information on the composition of past plant communities. However, a major limitation of the technique is that, unlike for pollen which can be species-specific in its morphology, a given plant species can produce several distinct phytolith types. Moreover, many of the most common phytolith types found in plant tissues (and soils) are quite non-specific, such as the rod-like forms. (Twiss (2001) gives the example of little bluestem (*Schizachyrium scoparium*) in which less than 5% of the siliceous residues of leaf tissues have any diagnostic value.) These dual problems of multiplicity and redundancy have always plagued attempts to extract taxonomic meaning from observations of phytoliths extracted from soils (Mulholland and Rapp, 1992a). There are no short-cuts around these problems, and other workers have relied on meticulous study of reference specimens from modern plant tissues in order to make sense of phytolith assemblages observed in soils.

2. Objectives

Therefore, the broad objective of this Seed Project is to assess the utility of soil phytolith evidence in reconstructing the pattern of non-forested and forested plant communities in the M-K area prior to the era of frequent prescribed burning. More specifically, we need to determine whether there are obvious differences in phytolith amounts and types in surface soils from under grassland, shrubland, and forest communities where recent anthropogenic burning has not been a major influence – if not, it would be difficult to use such evidence to help identify anthopogenic grass-dominated communities.

3. Methods

3.1 Field Work

For this pilot study, we wanted to choose a relatively compact study area containing a range of representative plant communities and degrees of fire influence (Table 1; Appendix 1). Wherever possible, we wanted to be able to link our work to well-documented study areas where we could benefit from previous work and perhaps enhance the value of future monitoring activities. Field work was conducted with helicopter support during July 24-26, 2001.

Table 1. Summary descriptions of study sites. (See Appendix 1 for site and soil profile photographs, and fuller descriptions.)

Site	Elevation (m)	Plant community	Recent prescribed fire influence
Bertha 1	1195	*Salix-Potentilla-Betula* shrubland	Absent
Nevis 1	1322	Scrub *Betula*-dominated	Absent
Nevis 2	1314	Scrub *Betula* - *Festuca*	Absent
Nevis 3	1321	*Elymus* - *Potentilla*	Absent
Nevis 4	1361	*Salix*-dominated	Absent
Nevis 5	1468	*Populus* forest	Absent
Nevis 6	1860	Alpine *Festuca* grassland	Absent
Hammett 1	1430	Mixed grassland	Absent
Hammett 2	1266	*Elymus* grassland	Yes
Withrow 1	1093	*Populus* forest	Yes

The Nevis Creek area immediately south of Mount Luckhurst (Figures 1 and 2) has been less influenced by anthropogenic fire than the adjacent areas of the Sikanni Chief River valley, and alpine plant communities including grasslands had been studied previously by Luckhurst (1973) and Lord and Luckhurst (1974). We selected five sites in grassland, shrub-dominated and forest communities at elevations from 1314 to 1468 m on the terraces of Nevis Creek, and the adjacent lower and middle portions of the south slope of Mount Luckhurst. A sixth site in alpine grassland at 1860 m was sampled on the next ridge to the south of Nevis Creek. (Fuller descriptions of the sites and plant communities are in the Appendix.)

In the Sikanni Chief River valley, we selected four sites near the Withrow, Bertha, and Hammett exclosures of the Range Reference Area program (Figure 1). The Bertha and Hammett exclosures were located in forested communities that had been modified by prescribed burning. Near the latter exclosure, we also included an upslope site (Hammett 1 – see Appendix 1) that appeared to have been unaffected by recent prescribed burning, as indicated by healthy shrubby cinquefoil (*Potentilla fruticosa*) bushes.

Figure 1. Study site locations in Muskwa-Kechika Management Area (approx. scale 1 : 650,000): 1-6 = Nevis Creek 1-6; 7 = Bertha (1); 8 = Hammett 1 & 2; 9 = Withrow 1.

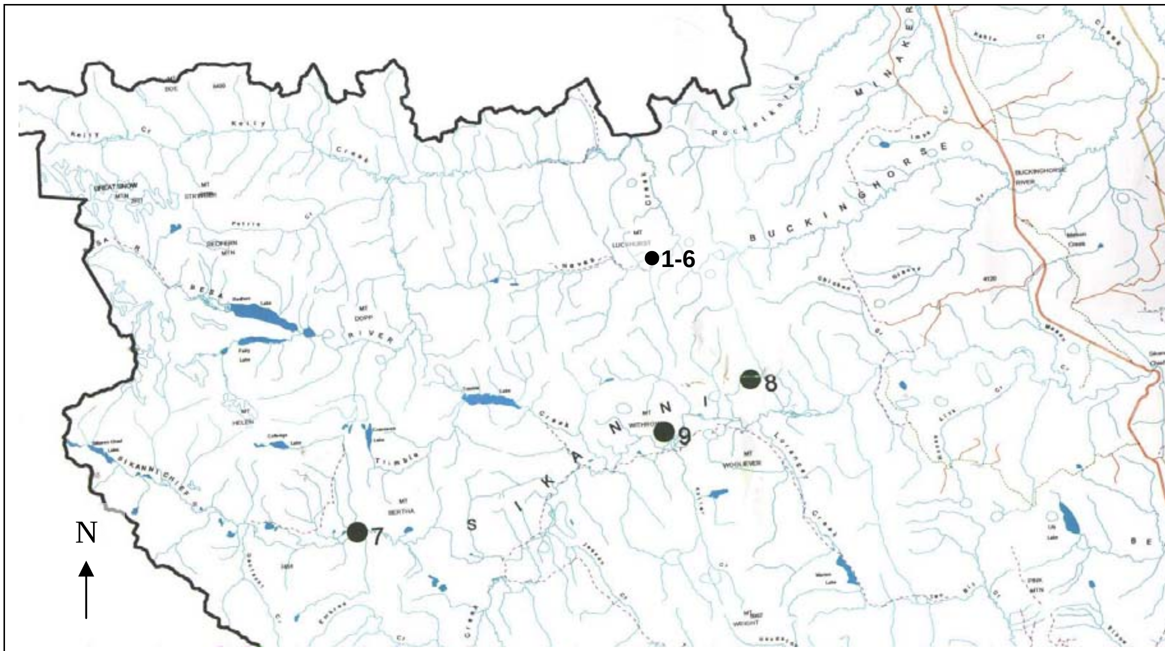
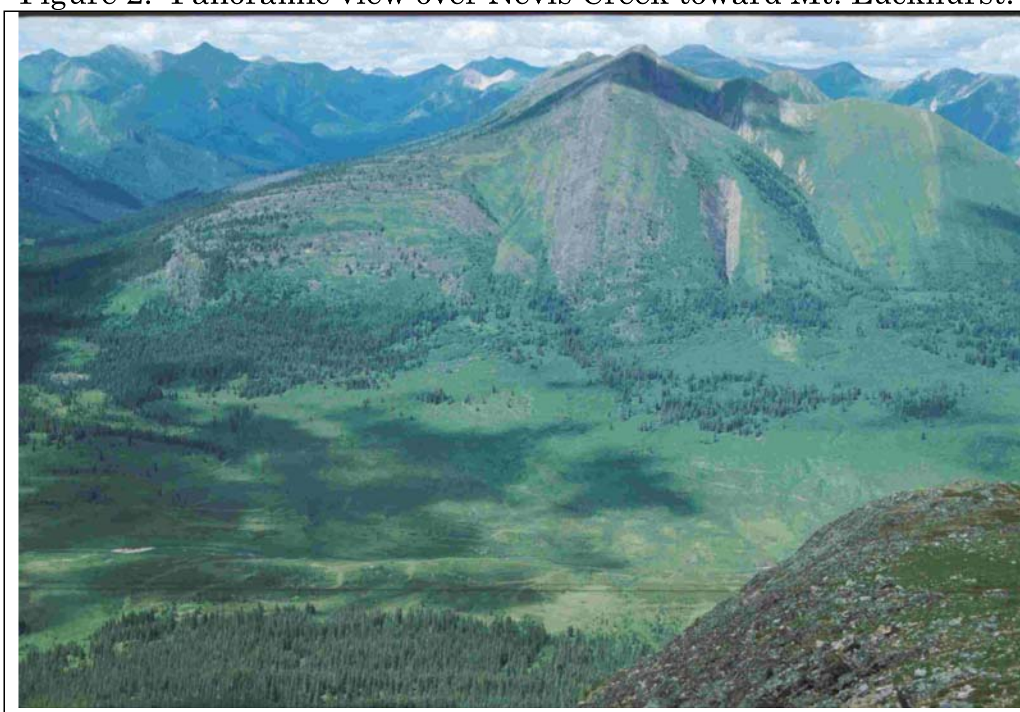


Figure 2. Panoramic view over Nevis Creek toward Mt. Luckhurst.



At each site, we selected a uniform and representative area for closer study, and recorded a visual estimate of the cover percentages of the major herbaceous and woody species. Basic site information (elevation, aspect, slope, landform) was recorded and an approximately 50-cm-deep soil pit was dug. Usually only the surface mineral soil horizons were sampled, because these were most likely to contain the maximum amount of phytoliths. Thicker A horizons were sampled at 10 cm depth increments. Based on observed soil morphology, tentative soil classifications were designated (Appendix 1). Samples of aboveground tissues of major herbaceous and woody species were collected at each site.

3.2 Laboratory Methods

Most phytoliths occur in the silt fraction (2-50 μm), and grass-derived phytoliths are particularly abundant in the medium silt (5-20 μm), as found in an earlier study in Alberta (Sanborn and Pawluk, 1983). Therefore, after destruction of soil organic matter with hydrogen peroxide, we isolated silt fractions by repeated sedimentation cycles, and further fractionated the silts into fine (2-5 μm), medium (5-20 μm), and coarse (20-50 μm). All separated silt fractions were freeze-dried, weighed, and stored, though only the medium silts were examined further in this study.

Originally, we had planned to do a density separation, using a sodium polytungstate solution (specific gravity 2.3 g cm^3), in order to obtain a relatively pure concentrate of phytolith for further examination by scanning electron microscope (SEM). However, the SEM at UNBC was out of service this spring, so we were unable to carry out this step.

Instead, we used a simpler method for estimating phytolith abundance and describing phytolith assemblages in the soil samples. For this pilot study, only the uppermost A horizon(s) was examined, as previous studies have shown that phytolith content decreases rapidly with depth in most soils (*e.g.* Norgren, 1973). A simple grain mount was prepared on a standard microscope slide, using Permount mounting medium. The slide were examined with a petrographic microscope, and the abundances of phytolith and non-opal mineral grains were tallied. Between 400 and 500 mineral grains were counted on each slide. Because phytoliths are composed of amorphous (non-crystalline) silica, they extinguish under cross-polarized light, and this optical property, together with their distinctive morphologies, allows relatively easy identification. Although many newer and more complex morphological classifications of phytoliths have been developed (Mulholland and Rapp, 1992b; Bowdery *et al.*, 2001), we used a combination of the relatively simple morphological categories recognized by Twiss *et al.*

(1969) and Norgren (1974). Phytolith content as a proportion of total soil mineral material was calculated from the grain count data and the silt fraction content.

Samples of three grass species were prepared to isolate phytoliths for microscopic study. We attempted to use a new microwave digestion method (Parr *et al.,* 2001), but encountered some difficulties in applying the method, and in the interest of expediency, used dry ashing in a muffle furnace (8 hours at 550 °C), and prepared a simple grain mount (as above) without any further chemical cleaning of the phytoliths in the residual ash. Recent work on phytoliths in the Chilcotin grasslands of central B.C. had found this to be a satisfactory method of preparing reference specimens (B. Chapman, Cariboo Forest Region, pers. comm.).

4. Results

4.1 Surface soil horizons

Expressed on an organic matter-free basis, the abundance of phytoliths in the 5-20 μm silt ranged from 0 to 2.6% of the total soil in the surface horizons examined (Table 2).

Table 2. Phytolith content of 5-20 μm silt as proportion of soil horizon (organic matter-free basis).

Site	Horizon	Phytolith % of horizon
Bertha1	Ah	0.4
Nevis1	Ah	1.4
Nevis2	Ah1	2.3
Nevis3	Ah1	0.2
Nevis4	Ah	1.9
Nevis5	Ahe	0.1
Nevis6	Ah1	0.0
Hammett1	Ah1	0.7
Hammett2	Ah1	2.1
Hammett2	Ah2	2.6
Withrow1	Ae	0.3

Morphologically, the phytoliths observed in the surface soil horizons are dominated by rod or elongate types (Appendix 2), usually smooth or rough. Many of the phytoliths in the “other” category appeared to be fragments of broken rods. (Representative photomicrographs of phytoliths obtained from these soils are shown in Appendix 3.) Since almost half the horizons examined contained less than 0.5% phytolith, the proportions reported in Appendix 2 represent a very small number of actual particles, so much larger grain counts would be needed to permit meaningful comparisons of assemblages between horizons and sites.

4.2 Reference specimens

Reference slides were prepared from ashed tissues of *Festuca altaica, Elymus innovatus*, and *Bromus inermis* ssp. *pumpellianus*, with the former two species representing the dominant grasses as most sites. In all cases, the predominance of rod or elongate types was obvious (Appendix 4).

5. Discussion

Phytolith concentrations in these surface mineral soils were at the lower end of the range of those found in other studies of mixedwood, grasslands, and transitional communities. For example, Sanborn and Pawluk (1983) found that phytoliths in the 5-20 μm silts comprised between 0.5 and 6.0% of Black Chernozemic Ah horizons in Alberta. Even higher values were found by Norgren (1973) in some Oregon grassland soils.

These results were somewhat unexpected in the case of soil profiles with thick Ah horizons (*e.g.* Hammett 1, Nevis 3 & 6) – a morphological feature usually associated with long-term grassland occupancy. Geomorphic processes may be partially responsible, since erosion and mass-wasting on these steeper sites may have led to mixing and incorporation of phytoliths to a greater depth in these soil profiles. In the case of the alpine site (Nevis 6), there was clear evidence for soil creep and solifluction. To deal with such sites, it might be more useful to estimate phytoliths on an area basis, for the full depth of the A horizons.

The observed low phytolith concentrations were consistent with long-term occupancy by forest or shrubs at the Bertha 1, Nevis 5 and Withrow 1 sites.

For these pilot results, the interpretive value of the phytolith data for vegetation history in relation to prescribed fire is rather mixed. We expected that Hammett 2 would show much lower phytolith concentrations in surface soils than Hammett 1, but the opposite was the case. In fact, the phytolith concentrations observed at Hammett 2 were almost the highest observed in this study. This was despite the field evidence that the Ah horizon at the latter site was apparently forming through transformation of the surface organic horizons of a pre-existing forest floor. Although the Withrow exclosure site has been affected by anthropogenic fire, it is still essentially an aspen forest, and the low content of phytoliths in the surface mineral soil is consistent with this.

Rod-type phytoliths, which occur across all grass taxa, were usually the most abundant types at most sites, and it is therefore difficult to make any interpretations of past vegetation types without examining large numbers of grains in order to detect the rarer, but more taxonomically useful types.

Because of difficulties in using the newer method of Parr *et al.* (2001) for preparing reference specimens from plant tissues, we were unable to prepare reference specimens of the quality desired, for the numbers of species that plant material had been sampled from. However, even with the relatively crude reference slides that were prepared, it was obvious that phytolith assemblages of these three grass species were dominated by rod or elongate types, which are non-specific within the grasses. Further work would be needed to prepare a proper reference collection of grass-derived and other phytoliths from this region.

6. Conclusions and Recommendations

For this relatively small number of sites, we did not find a clear relationship between phytolith content in the surface mineral soil horizon and present-day plant communities. Since grass-derived types tend to dominate soil phytolith assemblages, it was reasonable that we found low phytolith concentrations on forested sites. However, the reverse was not consistently observed – grass-dominated sites with thick, organic matter-rich Ah horizons did not always have correspondingly high phytolith concentrations. Therefore, for our primary goal of using soil phytolith evidence to help distinguish anthropogenic from "natural" grasslands, the results were not encouraging. In this dynamic mountain environment, with steep slopes and continual modification of landforms (*e.g.* alpine colluvial veneers, alluvial fans), the imprint of vegetation change can be obscured, since phytoliths accumulate in the uppermost soil horizons – the portion of the soil profile that is most vulnerable to disruption and/or removal.

However, phytolith studies do have great value as a tool paleoenvironmental research, as a growing list of recent symposia and monographs demonstrates (Meunier and Colin, 2001; Piperno, 1988; Rapp and Mulholland, 1992). We recommend that future research in the Muskwa-Kechika Management Area and adjacent areas of B.C. and Yukon should examine the potential for using phytoliths to identify and interpret buried soils preserved in depositional settings, such as alluvial fans and toeslope colluvium. When coupled with more detailed study of reference specimens than was possible in this pilot study, this approach may yield important evidence regarding the composition of past grass-dominated plant communities – vegetation types that are difficult to reconstruct from fossil pollens preserved in lake sediments. As a spinoff from this pilot study, we plan to examine phytoliths in a sequence of buried A horizons recently discovered in a remarkable alluvial fan site near Ft. St. John (M. Geertsema, pers. comm.).

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Appendix 1: Site Descriptions

<u>Nevis 1:</u> UTM 10-0472864-6357687 Elevation 1322 m

	
Site view	Soil profile

Site characteristics:

- gravelly terrace with sandy veneer

Soil characteristics:

- Eluviated Dystric Brunisol
- Sampled thin Ah or Hi horizon (0-4 cm depth)

Vegetation summary:

Plant Species	% Cover
Betula glandulosa	60
Moss/Lichen	20
Festuca altaica	5
Elymus innovatus	5
Other forbs	10

Nevis 2: UTM 10-0472868-6357643 Elevation 1314 m

Site view

Soil profile

Site characteristics:

- gravelly terrace

Soil characteristics:

- Orthic Sombric (or Melanic) Brunisol
- Sampled Ah1 (0-4 cm) and Ah2 (4-8 cm)

Vegetation summary:

Plant Species	% Cover
Betula glandulosa	40
Festuca altaica	40
Other forbs	10

Nevis 3: UTM 10-0472866-6357677 Elevation 1321 m

	
Site view	Soil profile

Site characteristics:

- Steep terrace slope (45%) between sites #1 and 2

Soil characteristics:

- Orthic Sombric (or Melanic) Brunisol
- Sampled Ah1 (0-10 cm), Ah2 (10-20 cm), and Ah3 (20-30 cm)

Vegetation summary:

Plant Species	% Cover
Elymus innovatus	80
Potentilla fruticosa	40
Other forbs	15

<u>Nevis 4:</u> UTM 10-0472765-6358086 Elevation 1361 m

	
Site view	Soil profile

Site characteristics:
- Mid-slope position on fluvial fan
- 15% slope, South aspect

Soil characteristics:
- Orthic Dystric (or Eutric) Brunisol
- Sampled Ah horizon (0-7 cm)

Vegetation summary:

Plant Species	% Cover
Salix sp.	60
Betula glandulosa	10
Festuca altaica	15
Elymus innovatus	10
Carex sp.	5

Nevis 5: UTM 10-0472812-6358736 Elevation 1468 m

	
Site view	Soil profile

Site characteristics:

- Upper slope, colluvial or morainal blanket over bedrock
- 40% slope, South aspect

Soil characteristics:

- Orthic Dystric (or Eutric) Brunisol
- sampled Ahe horizon (0-7 cm)

Vegetation summary:

Plant Species	% Cover
Populus tremuloides	60
Epilobium angustifolium	30
Lathyrus ochroleucus	20
Elymus innovatus	5
Other forbs	5
Festuca altaica	trace

Nevis 6: UTM 10-0473181-6354941 Elevation 1860 m

Site view

Soil profile

Site characteristics:
- alpine site with solifluction lobes
- colluvial or morainal veneer over bedrock

Soil characteristics:
- Orthic Sombric (or Melanic) Brunisol
- Sampled Ah1 (0-10 cm), Ah2 (10-20 cm) and Ah3 (20-30 cm)

Vegetation summary:

Plant Species	% Cover
Festuca altaica	50
Mertensia paniculata	20
Anemone sp.	10
Moss	20

Bertha 1: UTM 10-0451608-6338262 (adjacent to exclosure) Elevation 1195 m

	
Site view	Soil profile

Site characteristics:
- Sandy fluvial terrace
- 3-5% slope, South aspect

Soil characteristics:
- Cumulic Regosol
- Sampled Ah (0-5 cm), C1 (5-18 cm), and Ahb (18-20 cm)

Vegetation summary:

Plant Species	% Cover
Salix sp.	40
Potentilla fruticosa	10
Betula glandulosa	10
Carex sp.	20
Festuca altaica	10
Elymus innovatus	5
Other forbs	5

Withrow 1: UTM 10-0478085-6343422 (adjacent to exclosure) Elevation 1093 m

	
Site view	Soil profile

Site characteristics:
- Fluvial terrace (?)

Soil characteristics:
- Eluviated Dystric Brunisol
- Sampled Ae horizon (0-3 cm)

Vegetation summary:

Plant Species	% Cover
Populus tremuloides	40
Populus balsamifera ssp. *balsamifera*	5
Lathyrus ochroleucus	15
Astragalus americanus	10
Elymus innovatus	10
Epilobium angustifolium	5
Rosa acicularis.	5

Hammett 1: UTM 10-0484236-6346984 Elevation 1430 m

Site view

Soil profile

Site characteristics:

- Upper slope, morainal veneer over sandstone bedrock
- ~ 50% slope, South aspect

Soil characteristics:

- Orthic Sombric Brunisol
- Sampled Ah1 (0-10 cm), Ah2 (10-20 cm), and Ah3 (20-30 cm)

Vegetation summary:

Plant Species	% Cover
Potentilla fruticosa	10
Poa sp.	10
Elymus innovatus	15
Artemisia frigida	10
Agropyron sp.	20
Festuca sp.	5
Bare ground	30

Hammett 2: UTM 10-048250-6346578 Elevation 1266 m

	
Site view	Soil profile

Site characteristics:

- Colluvial veneer over bedrock (black shale)

Soil characteristics:

- Orthic Dystric Brunisol (with Ah forming within former forest floor organic horizons)
- Sampled Ah1 (0-5 cm), Ah2 (or Hi?) (5-9 cm), and Bm (9-20 cm)

Vegetation summary:

Plant Species	% Cover
Elymus innovatus	60
Astragalus americanus	20
Populus balsamifera ssp. *balsamifera*	5
Rosa acicularis	10
Other forbs	5

Appendix 2: Soil Phytolith Assemblages[1]

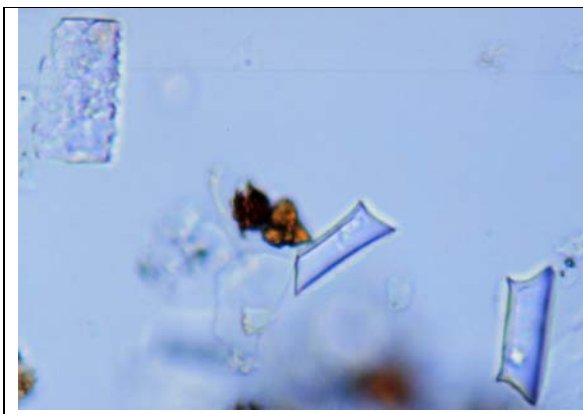
Site	Horizon	Rod - smooth	Rod - wavy	Rod - rough	Rod - spiny	Chloridoid	Festucoid	Panicoid	Hookbase	Hair	Other	N[2]
Bertha 1	Ah	37.5	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	8
Nevis 1	Ah1	49.1	5.5	20.0	7.3	1.8	0.0	0.0	1.8	5.5	9.1	55
Nevis 2	Ah1	36.4	4.5	4.5	2.3	20.5	0.0	0.0	0.0	0.0	31.8	62
Nevis 3	Ah1	30.0	20.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	40.0	10
Nevis 4	Ah	38.0	16.0	18.0	0.0	4.0	2.0	0.0	0.0	0.0	22.0	50
Nevis 5	Ahe	20.0	0.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0	40.0	5
Nevis 6	Ah1	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1
Hammett 1	Ah1	15.2	15.2	18.2	0.0	0.0	9.1	0.0	0.0	3.0	39.4	33
Hammett 2	Ah1	24.1	27.8	25.3	0.0	0.0	6.3	0.0	0.0	0.0	16.5	79
Hammett 2	Ah2	29.2	19.4	11.1	1.4	0.0	0.0	4.2	0.0	0.0	34.7	72
Withrow 1	Ae	50.0	16.7	16.7	0.0	0.0	0.0	0.0	0.0	0.0	16.7	6

[1]terminology adapted from Twiss *et al.* (1969) and Norgren (1973); expressed as % of grains in 5-20 µm silt counted per slide.(total count approx. 400 grains per slide).
[2]actual total number of phytoliths counted per slide.

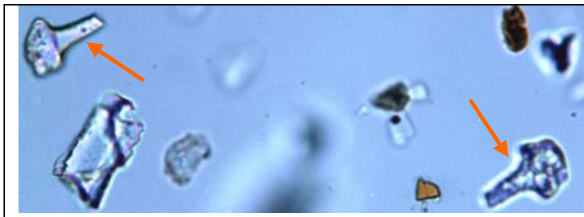
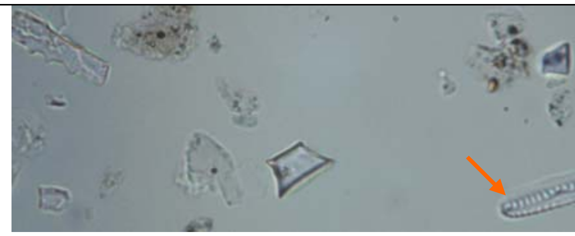
Appendix 3: Examples of Phytoliths in Surface Soil Horizons

Nevis 1 site: Ah1 horizon (5-20 μm silt fraction)

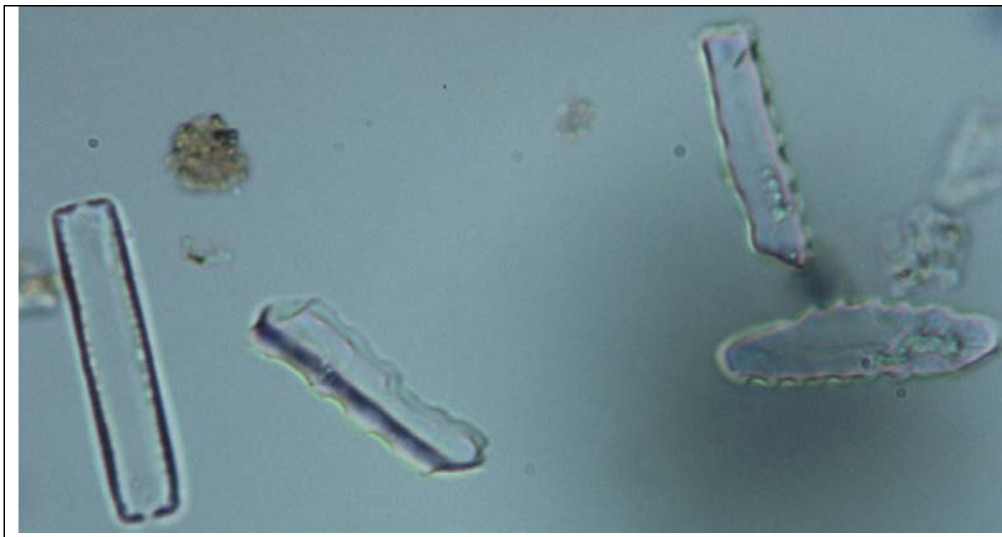
	
Rough rod type	Spiny rod type

	
Short rod-like types	Hair cell (?) in centre; broken rough rod at bottom.

Nevis 2 site: Ah1 horizon (5-20 µm silt fraction)

	
Hair cells (?) in upper left and lower right (arrowed).	Various rods and fragments of phytolith; diatom in lower right (arrowed).

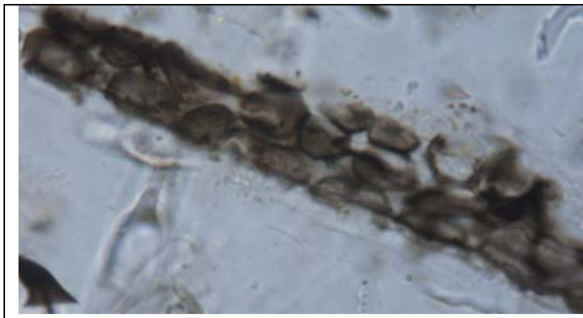
Hammett 2 site: Ah1 horizon (5-20 µm silt fraction)


Various rod-like phytoliths.

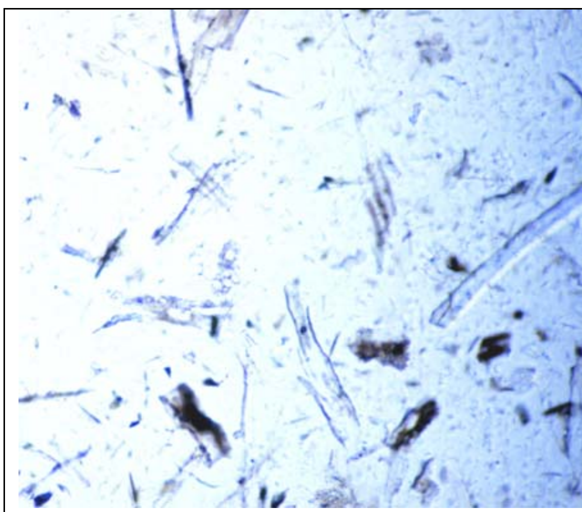
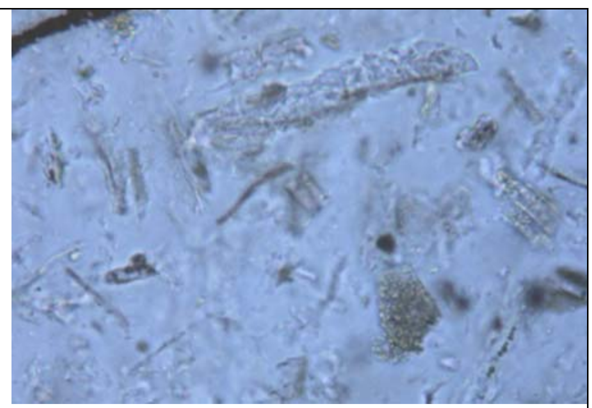
Appendix 4: Examples of Phytoliths from Ashed Grass Leaf Tissues

(approx. 400 X magnification, unless noted otherwise)

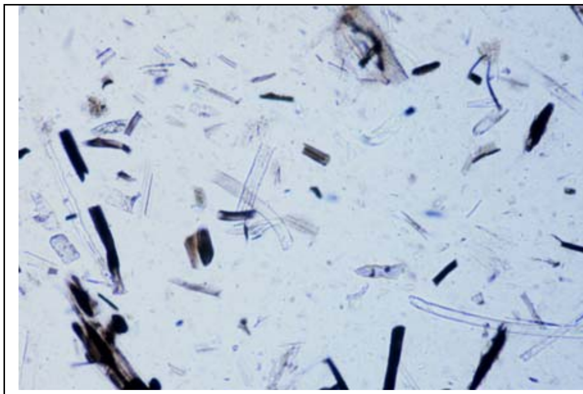
Festuca altaica

	
Rough rod-like type	Hair cell (?) (arrowed)

Elymus innovatus

	
Note dominance of rod-like types (approx. 100 X magnification)	Detail view

Bromus inermis ssp. *pumpellianus*

	
Note dominance of rod-like types (approx. 100 X magnification)	Detail view; note other morphological types (*e.g.* hook base – arrowed)