Comparison of Radiocarbon Dating of Buried Paleosols Using Arbuscular Mycorrizae Spores and Bulk Soil Samples

Colin E. Thorn, Robert G. Darmody, Johan Holmqvist, John C. Dixon

Introduction

- This is a preliminary investigation of the use of arbuscular mycorrizae spores as a widespread, perhaps universal, dating tool for paleosols.
- The dating of paleosols is difficult because the differing fractions of soil organic material (SOM) decay and turn over at different rates. This produces an inherent fuzziness to paleosol dates depending on the specific SOM admixture in a paleosol and the vicissitudes of the climate since development. SOM samples may be also contaminated by younger or older carbon sources.

(Vesicular-) arbuscular mycorrizae

- Mycorrhizae are a symbiosis between a plant and a fungus. They are found on the roots of a very large variety of plants in many environments and are thus focused in the A horizon of soils. Mycorrhizae reproduce in a variety of ways including spores. Once produced the spores remain quiescent in the soil until adequate conditions for growth occur.

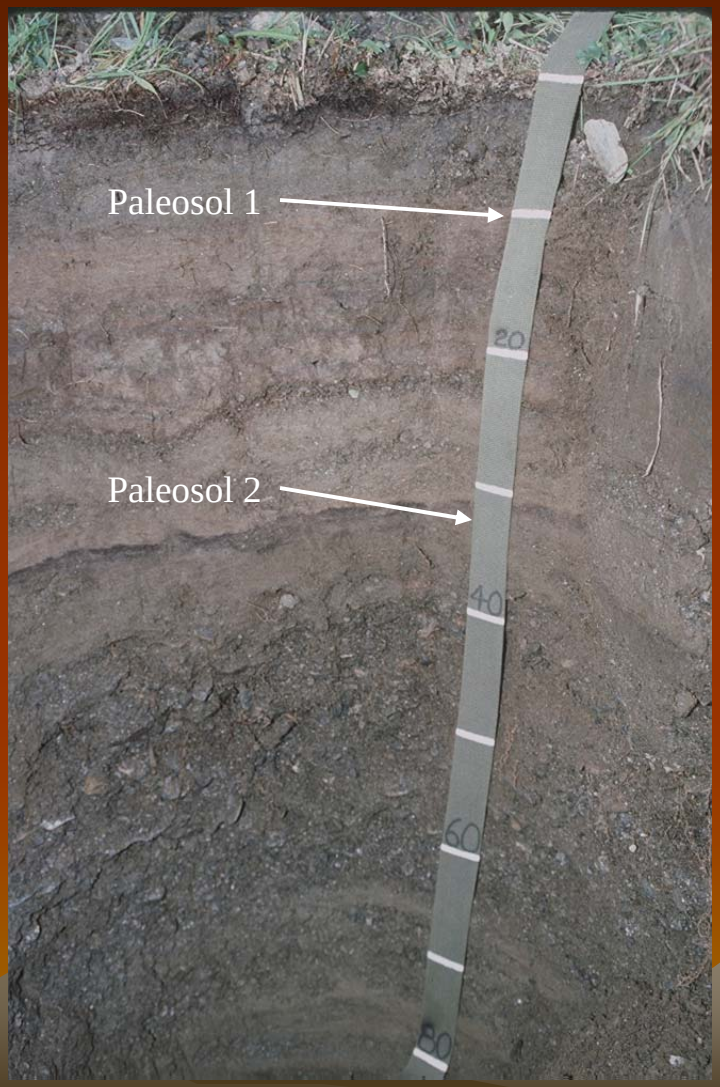
(Vesicular-) arbuscular mycorrizae

- The net result is that spores may sit inert in a soil for long periods of time – essentially behaving within a paleosol as ‘fossils’.

Field Sampling

- In the field spores are extracted by digging a soil pit which exposes paleosols.
- The pit is then extended so that it may be excavated in a series of benches each of which exposes a paleosol as a surface area, and not just as an edge.

Kärkevagge - Soil Pit with Paleosols



Soil Pit Sampling for Spores

Laboratory Preparation

- In the laboratory the bulk soil sample is soaked in distilled water, agitated, and permitted to sediment.
- The spores separate from the other organics, and may then be extracted using pipette and microscopic inspection.
- Accelerator mass spectrometry (AMS) means that samples of spores, totaling <10 mg may now be used for dating.

Advantages / Disadvantages

- Consequently, spores are potentially a very useful dating source, being: widespread, uncontaminated, and essentially isolated within a paleosol.
- The main problems are:
  - somewhat tedious, manual extraction
  - the need to establish a preparation protocol for sample analysis
  - The need to establish the relationship of spore dates to other datable material.

Pretreatment for Dating

- Wash:
  - acid-only = less aggressive
  - Acid-base-acid = more aggressive
- Combustion (°C):
  - 400 (all material <400) in oxygen
  - 800 (all material 400-800) in oxygen
  - 900 (all material <900) with CuO

Pretreatments

- All spore samples = ABA900
- SOM samples:
  - A400
  - ABA400
  - ABA800
  - ABA900
- Not all SOM samples received all pretreatments or ignition temperatures.

Spore vs. SOM Depth, an Example

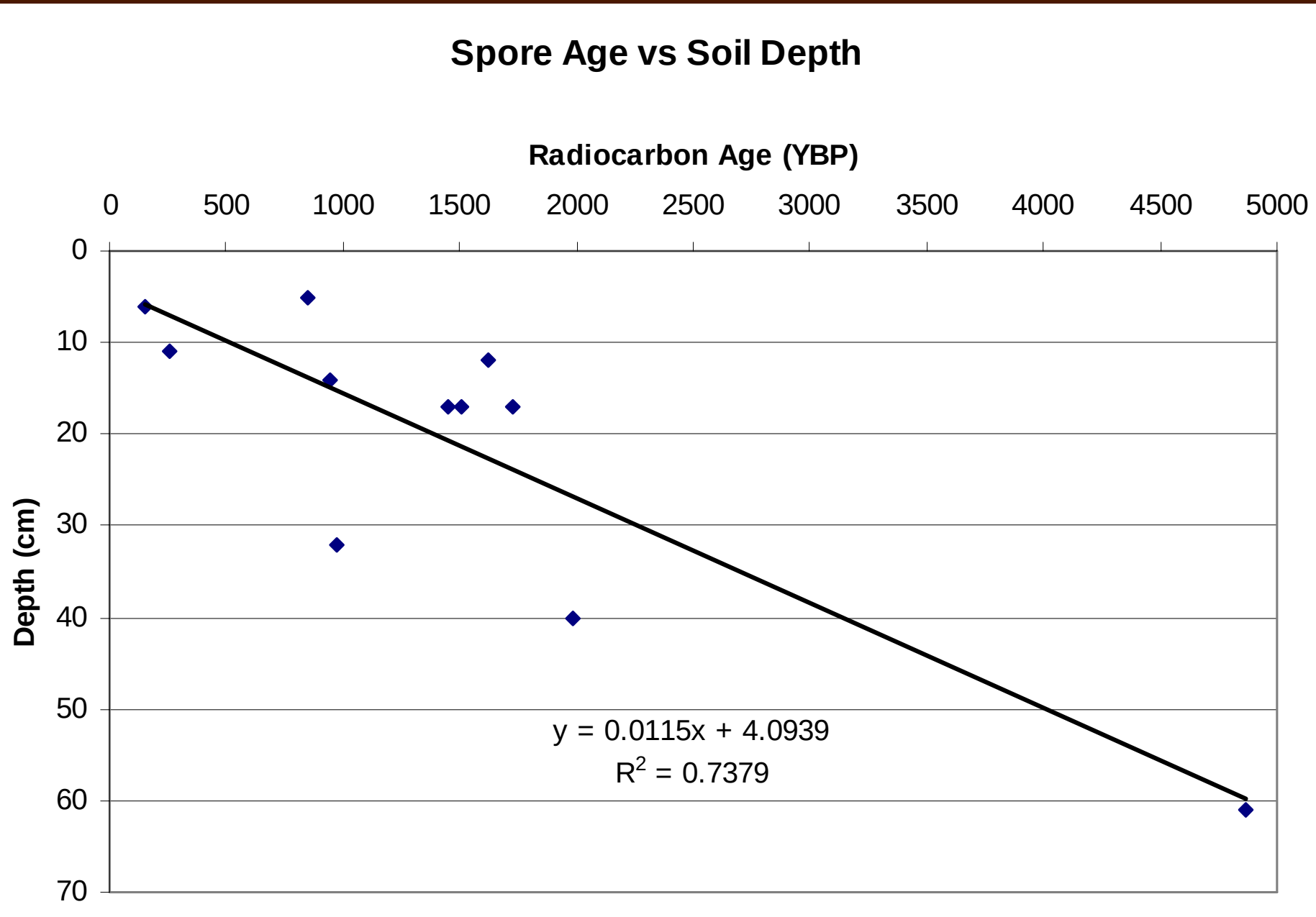
Paleosol	Spore Date	SOM(ABA900)
PA1	153 ± 37	35,860 ± 930
PA3	976 ± 37	30,820 ± 600
PA3	918 ± 37	
PA4	1,455 ± 49	9,780 ± 120

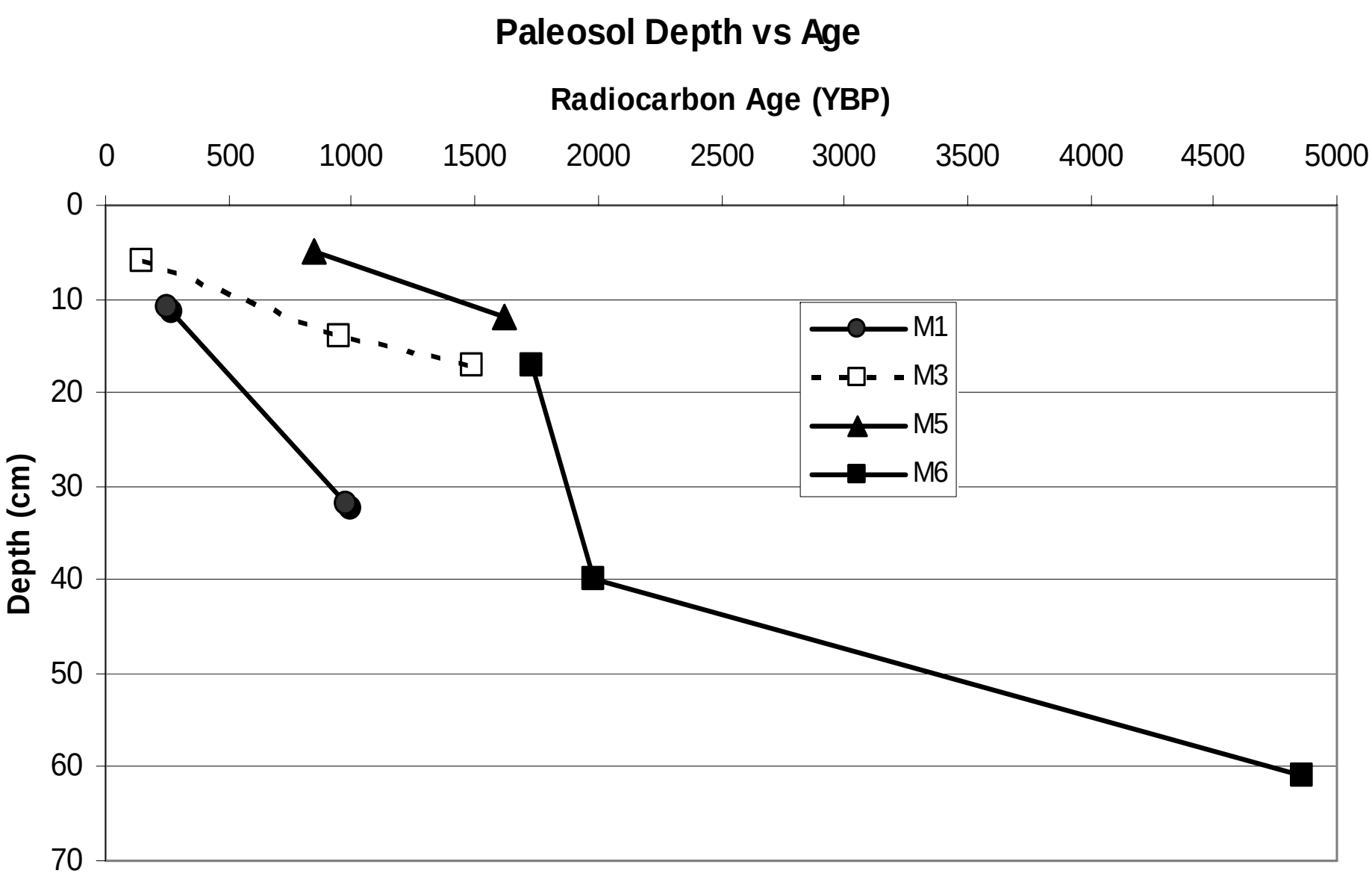
- PA# increases with increasing soil depth

SOM Dates with Variable Pretreatments and Ignition Temperatures – an Example

Paleosol	SOM(ABA400)	SOM(ABA900)
PA1	2,470 ± 120	35,860 ± 930
PA3	2,980 ± 140	30,820 ± 600
PA4	1,763 ± 44	9,780 ± 120

- PA# increases with increasing soil depth. Pit M3.


Spore Age vs Soil Depth
Radiocarbon Age (YBP)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Depth (cm)
0
10
20
30
40
50
60
70
y = 0.0115x + 4.0939
R2 = 0.7379


Paleosol Depth vs Age
Radiocarbon Age (YBP)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Depth (cm)
0
10
20
30
40
50
60
70
M1
M3
M5
M6

Some Problems - an Example

- Two different ways of splitting spores:

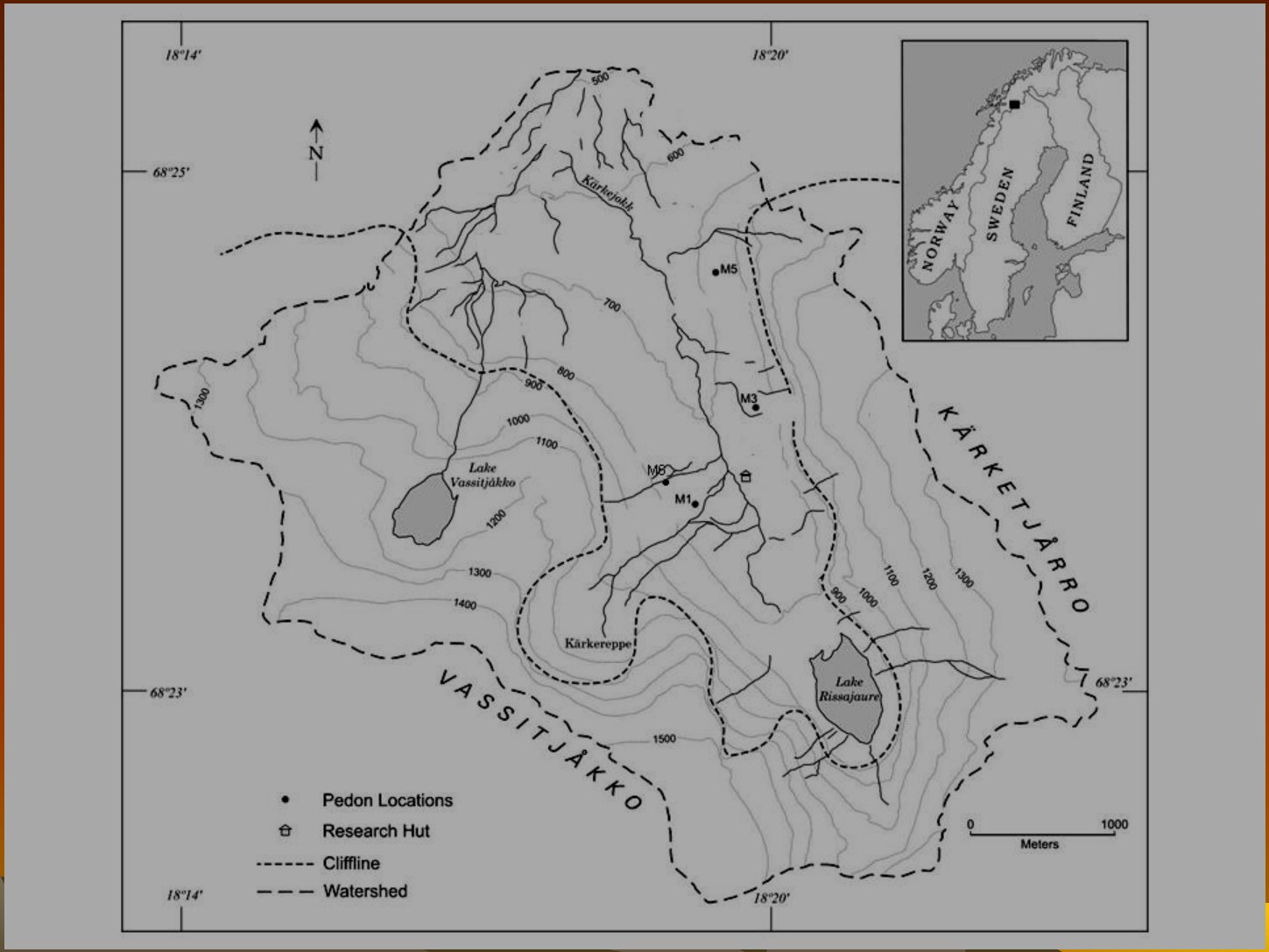
- Spores >0.6 mm (976 ± 37) versus spores <0.6 mm (918 ± 37). Variable dates from a single paleosol.

- Spores <1.0 g/cm^3 (1,275 ± 41) versus spores >1.0 g/cm^3 (1,752 ± 42). Variable dates from a single paleosol.

A Brief Interpretation

- The primary project objective was technique development. However, some preliminary interpretive comments may be offered.

Kärkevagge Research Area



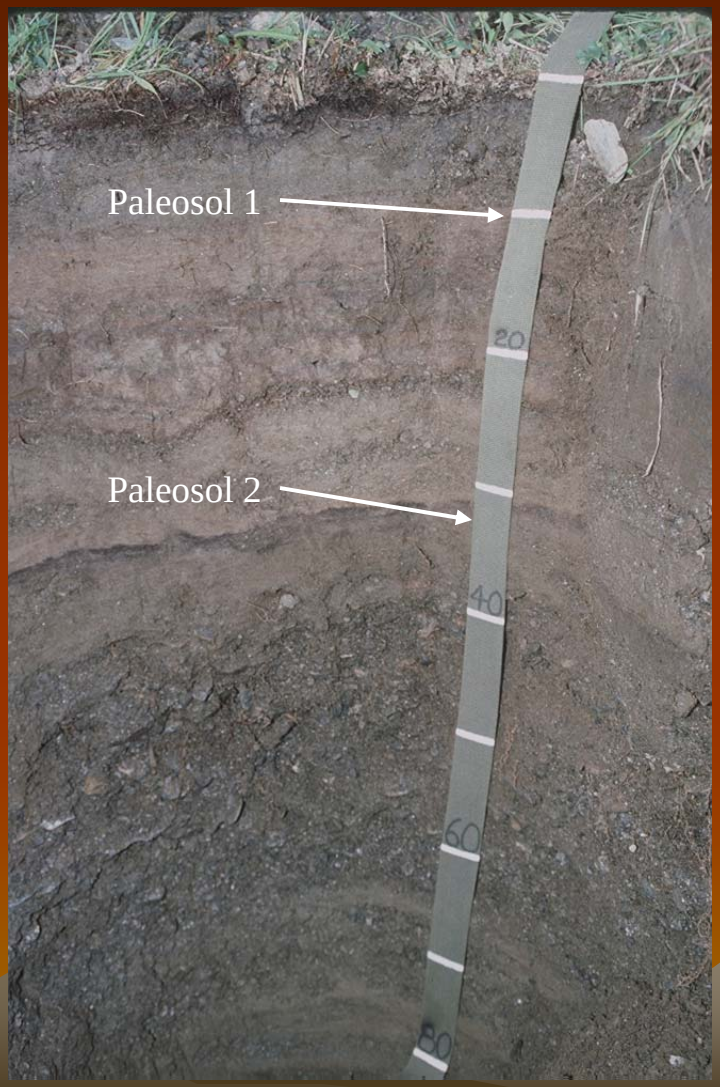
Kärkevagge Research Area

Kärkevagge Research Area

Colluvial Slope

Cliff, Slope, & Pit

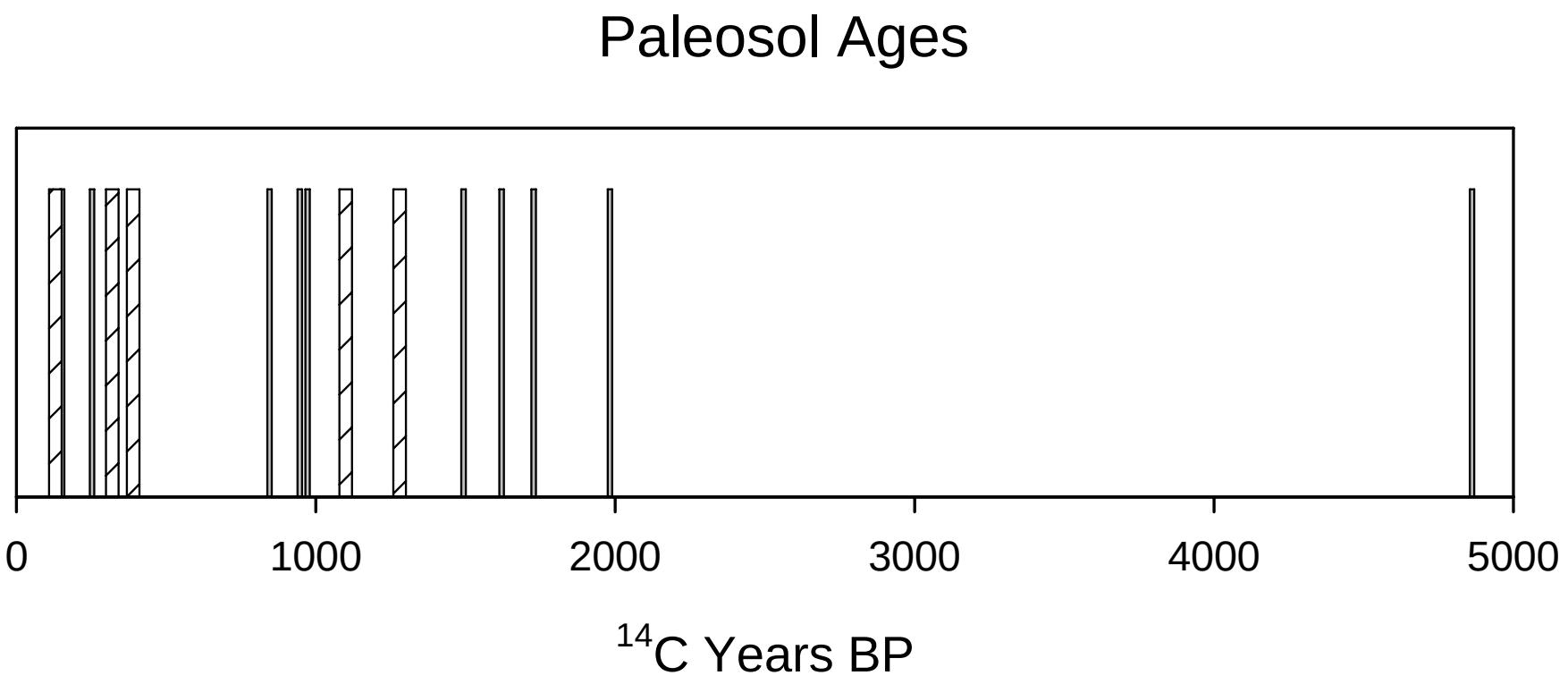
Kärkevagge - Soil Pit with Paleosols



A Brief Interpretation of the Sites

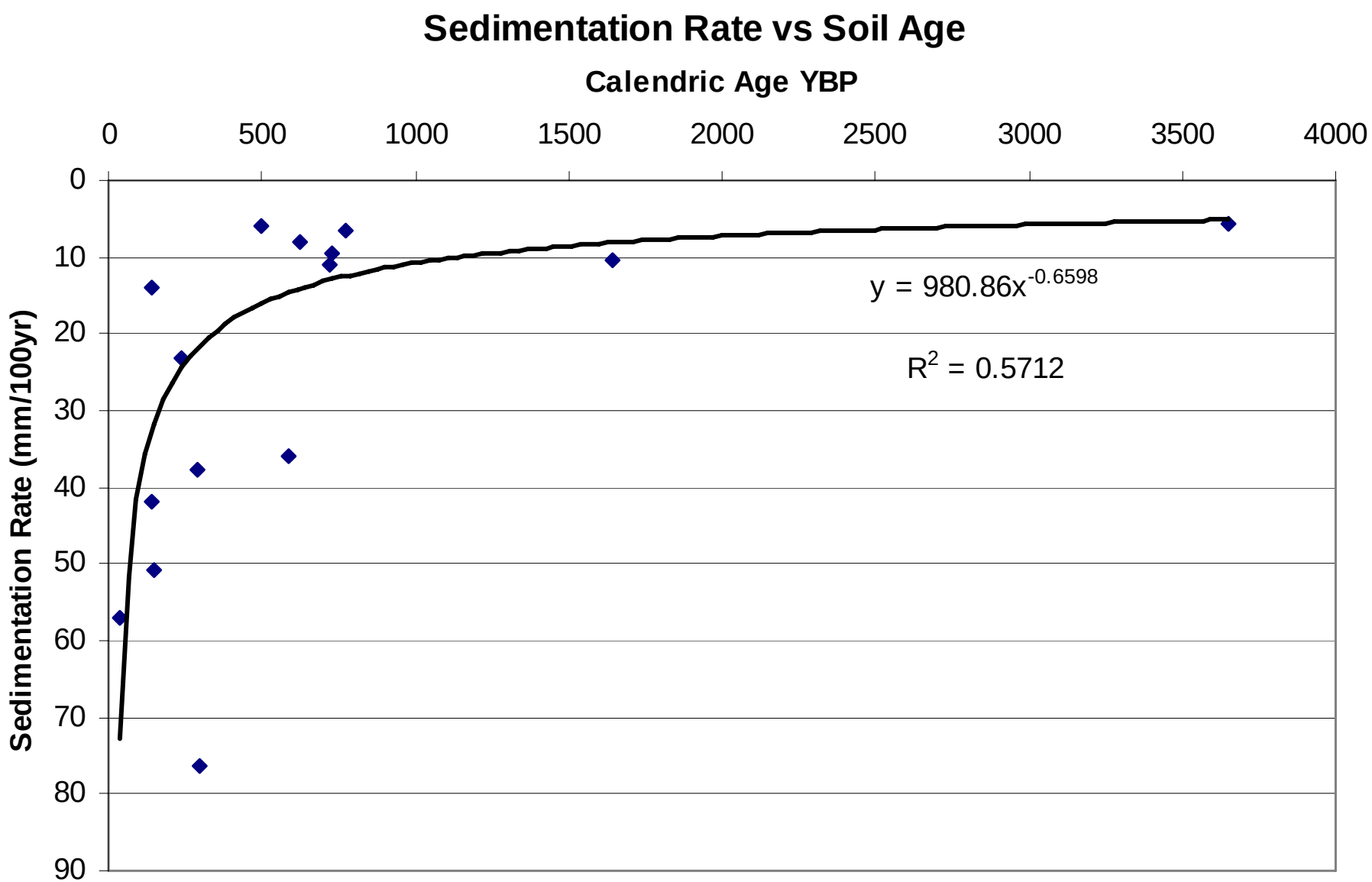
- Accepting the spore dates as valid it is possible to offer some preliminary comments on the character of the paleosols investigated.
- Paleosols within ~60 cm of the surface are surprisingly old. Soils at ~4-11 cm are 153 – 846 ^{14}C YBP. At ~ 60 cm soils are 4862 ± 72 ^{14}C YBP. Paleosols are generally only 0.5 – 1.0 cm thick.

Timeline of paleosols dated in this study. Paleosols reported by Holmqvist and Schlyter (2000) from the same vicinity using the same technique are shown in stripes.



Soil Accumulation Rates

- Simple accumulation (depth divided by radiocarbon years) rates are slow, 6 – 76 mm/100 calendar years.
- High variability strongly suggests episodic slope behavior.
- Generally, accumulation rates appear to be increasing.


Sedimentation Rate vs Soil Age
Calendric Age YBP
0
500
1000
1500
2000
2500
3000
3500
4000
Sedimentation Rate (mm/100yr)
0
10
20
30
40
50
60
70
80
90
y = 980.86x-0.6598
R2 = 0.5712

Conclusions

- There is still work to do. However, the ubiquity of spores and their fossil-like behavior suggest that they are worth further investigation.
- There is the prospect of developing a consistent and reliable dating metric from spores, or some subset of spores.