Ornithogenic (bird-formed) Soils

Extensively developed in Antarctica and rare outside of Polar regions

Characterized by a specific lithology due to penguin nesting behavior

Includes a combination of soil, pebbles, guano, highly rich in organic matter (feathers, bone, eggshell, prey remains)


Ornithogenic Soil
Gravel terrace and interface

Biscoe Point, Antarctica

Pebble concentration

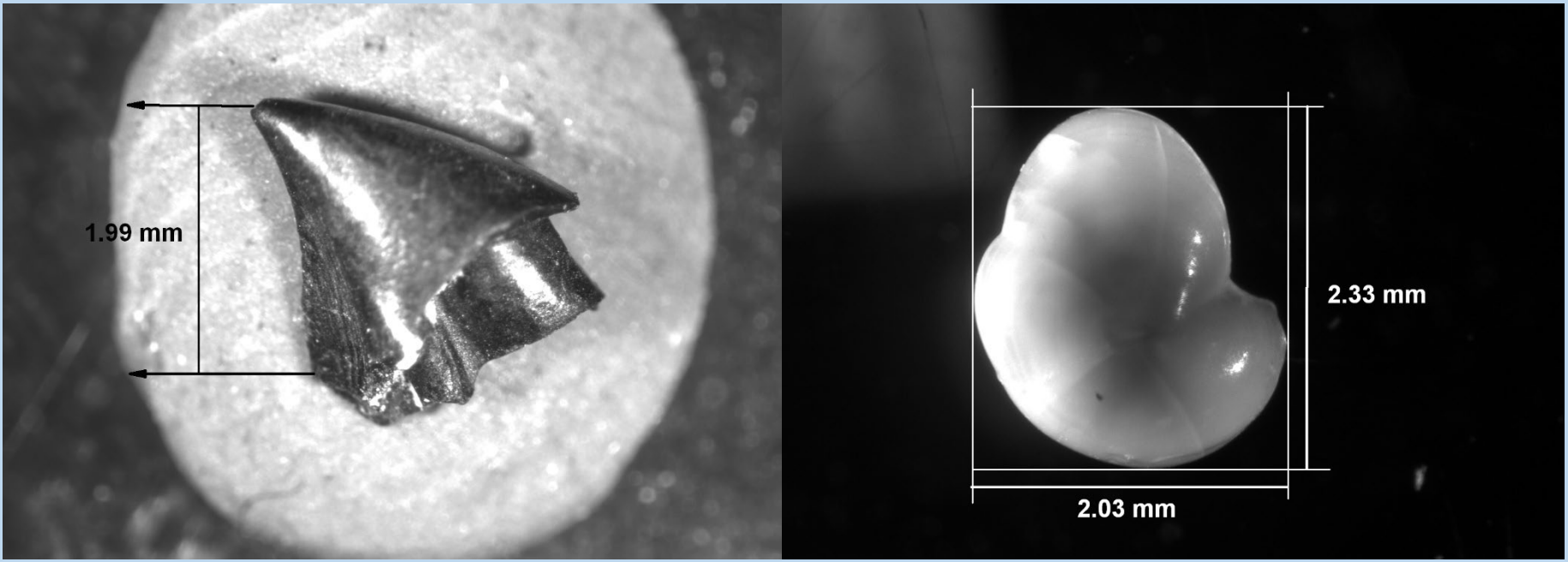
Grass and lichen

The enriched nutrients in the soil enhance vegetative growth


Soils dry over time, but still retain guano smell

Squid beak

Fish otolith



Measurements provide good correlation for size of prey in life

These soils provide a rich assortment of preserved tissues of penguins and their prey:

penguin bones and feathers, mummies
eggshells
fish bones, otoliths
squid beaks

Invaluable for numerous types of analyses:

Radiocarbon dating to obtain occupation history
Ancient DNA for evolutionary rates in penguins
Stable Isotope analyses to investigate dietary shifts through time
Oxygen isotope analyses of prey remains (otoliths, squid beaks)
RNA viruses in birds

Ross Sea has longest record for Adélie Penguins in Antarctica and their occupation history there provides important data on how penguins respond to climate change

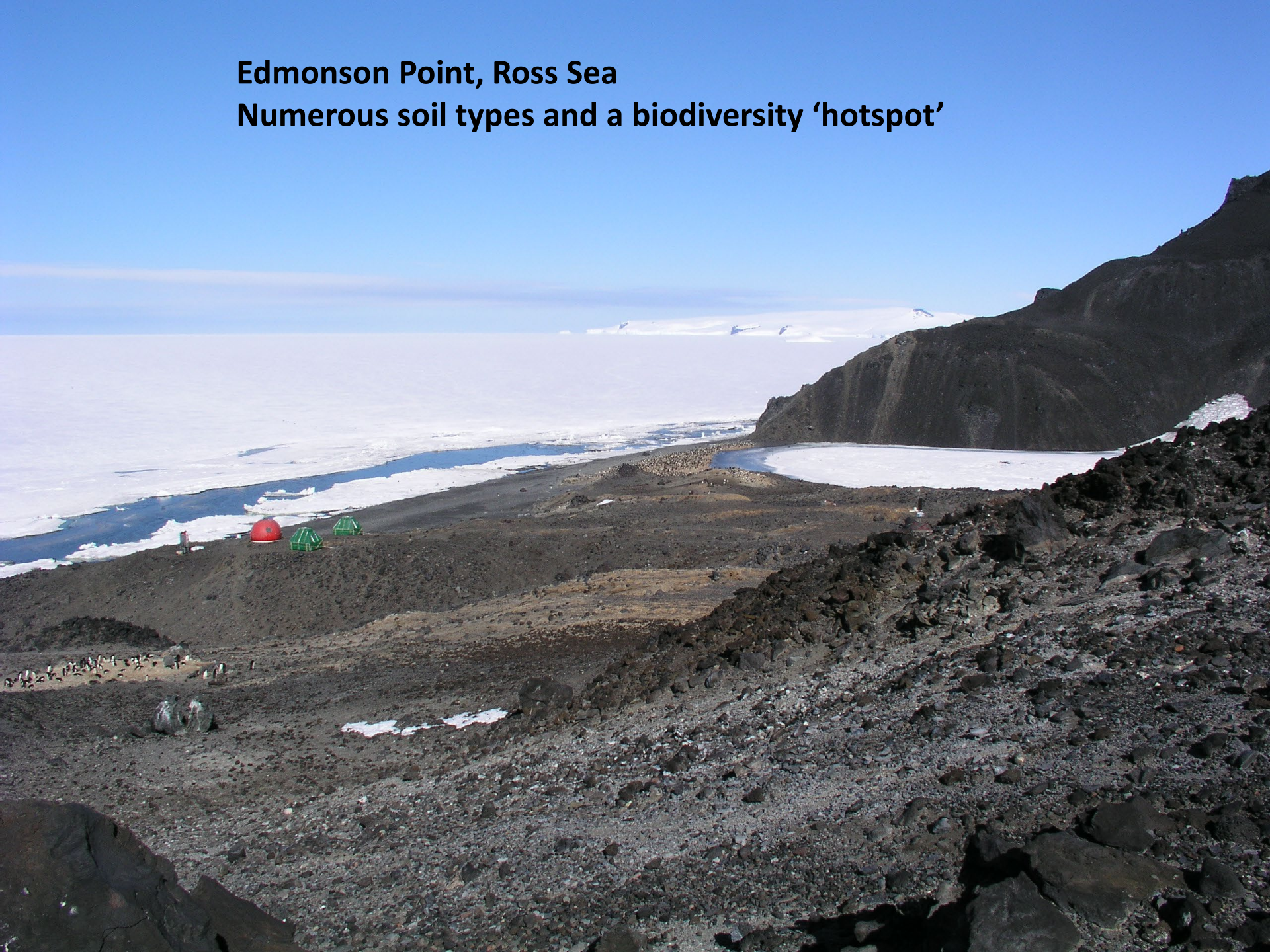
Ornithogenic soil microbiota

At active penguin colonies, soil is dominated by bacteria at 92% of total biomass

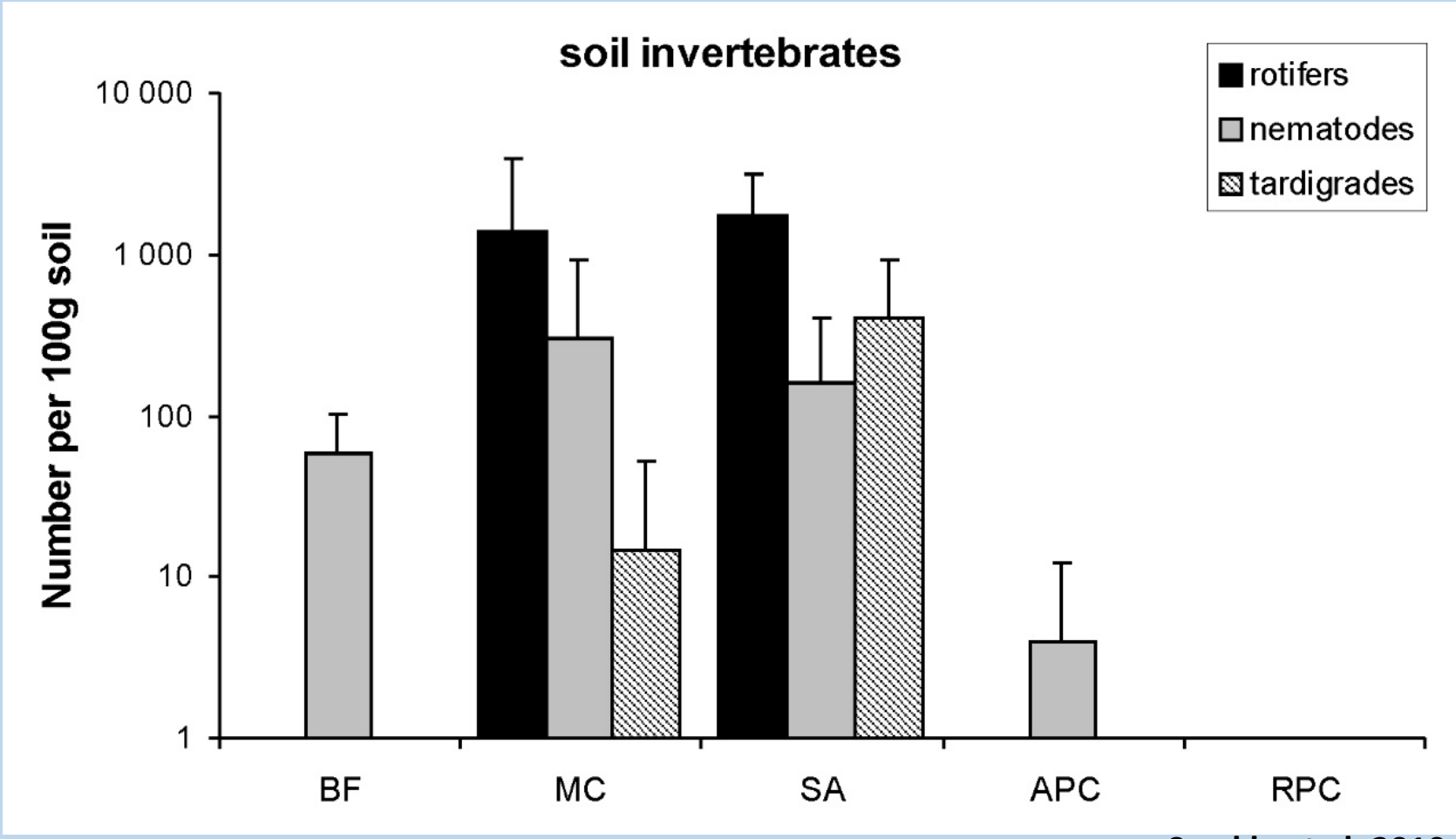
Farther from colonies, algae dominates sediments (up to 96% of biomass)

Surprisingly, invertebrates (nemotodes, springtails) were not more diverse in active colony soils, tardigrades absent

Possible due to high nutrient and salt content limiting invertebrate abundance and diversity

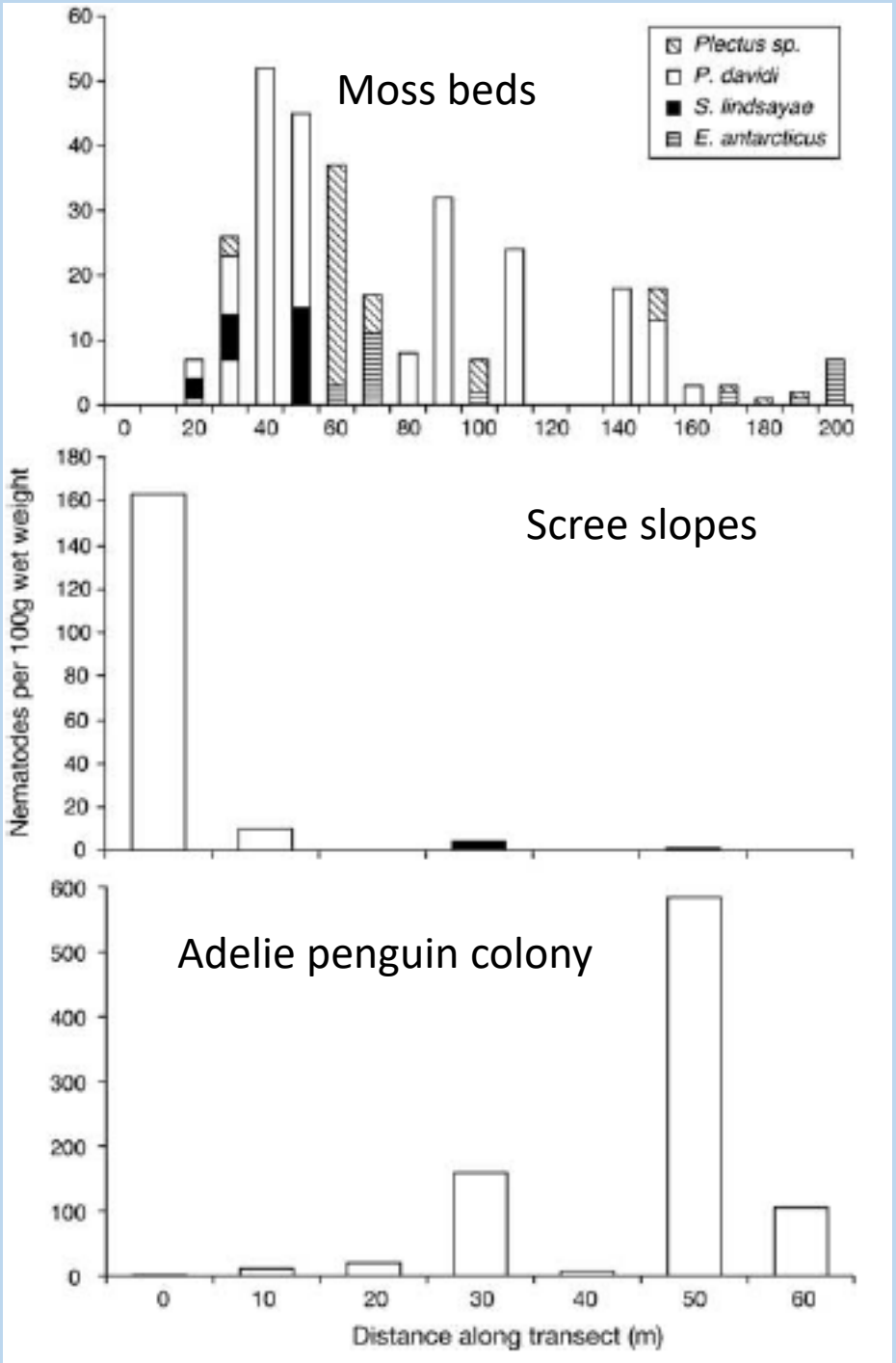

Edmonson Point, Ross Sea
Numerous soil types and a biodiversity ‘hotspot’

BF = barren fellfields
MC = moss communities
SA = seepage areas
APC = active penguin colonies
RPC = relict penguin colonies



Smykla et al. 2010


Cape Hallett



Cape Hallett

- *S. lindsayae*
  - Dominates dry saline soils
  - negatively affected by >10°C
  - yeast and bacterial feeder
- *E. antarcticus* and *Plectus sp.*
  - dominate mosses
  - high soil moisture and high organic matter content
- *P. davidi*
  - coastal areas
  - ornithogenic soils
  - microbivore
  - highest growth rates 25-30°C

Raymond et al. 2013


Note algae outside of colonies
Trampling by penguins prevents growth within the colony


After the colony is abandoned, plant biomass outside the colony continues to dominate
Lichens replace algae as the soils dry

Lichen growth over an ancient colony

Bio-elements in Ornithogenic Soils

--defined as those mineral elements that accumulate in soil due to deposition of guano

--show distinct profile with depth in natural versus ornithogenic deposits

--found in ornithogenic soils and sediments

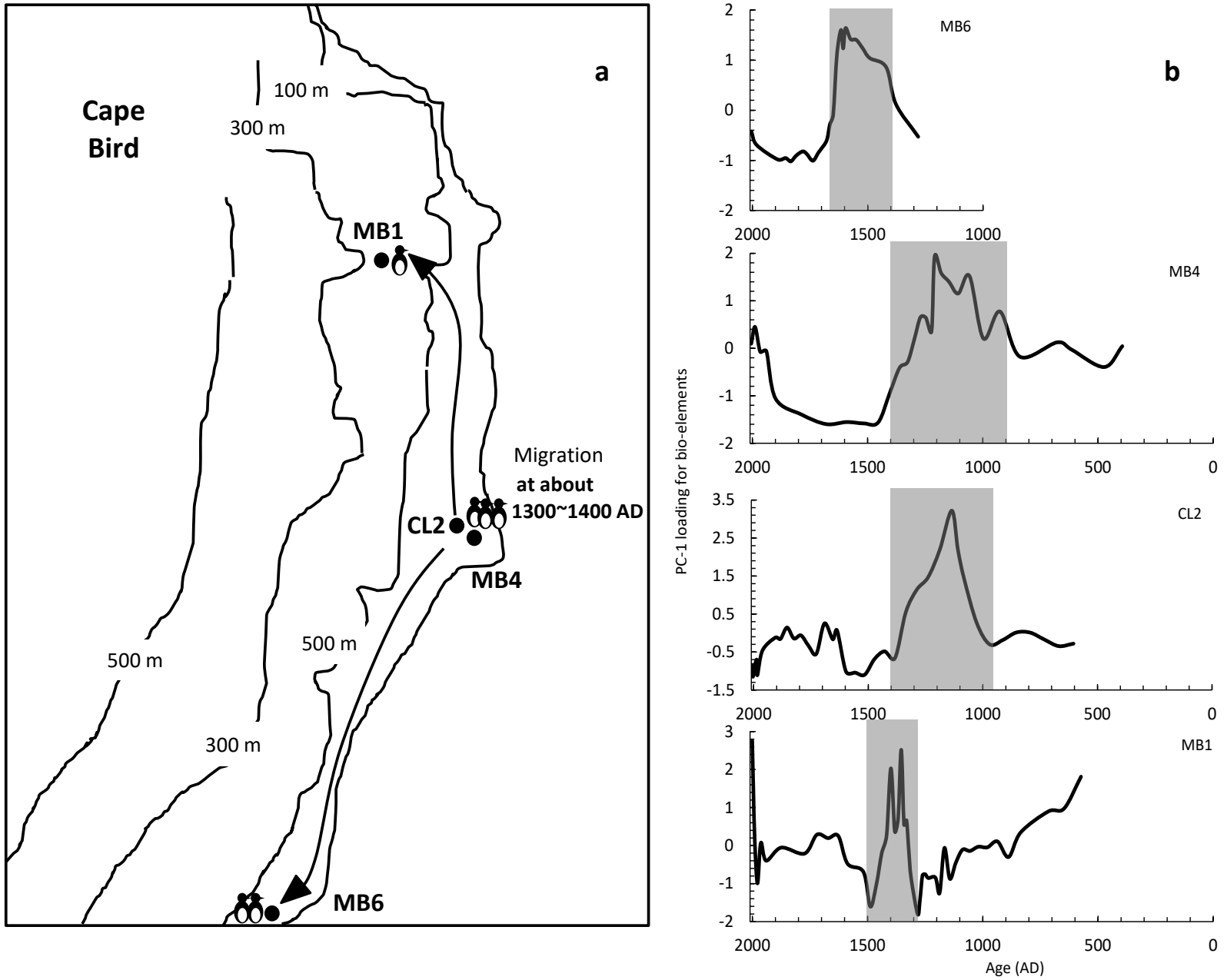
--can be used to assess past population sizes, occupation history

--first investigated in 1950s and 1960s, considerable more work in past decade by Chinese scientists

Bio-elements in Ornithogenic Soils

Phosphorus
Nitrogen
Zinc
Fluorine
Barium
Sulfur
Calcium
Copper
Selenium
Strontium
Cadmium
Arsenic
Sodium


Cape Bird, Ross Island



Penguin population change inferred from four profiles from Cape Bird and a possible migration route during 1300~1400 AD.

Quiz

1. What are ornithogenic soils and why are they restricted mainly to Antarctica?

2. What is the biological ‘archive’ in these soils?

3. What are some of the studies that can be completed with this archive?

4. What are bio-elements in ornithogenic soils?

5. Where are soil invertebrates most diverse at active penguin colonies and why do ornithogenic soils have low diversity?