Terrestrial Ecosystems

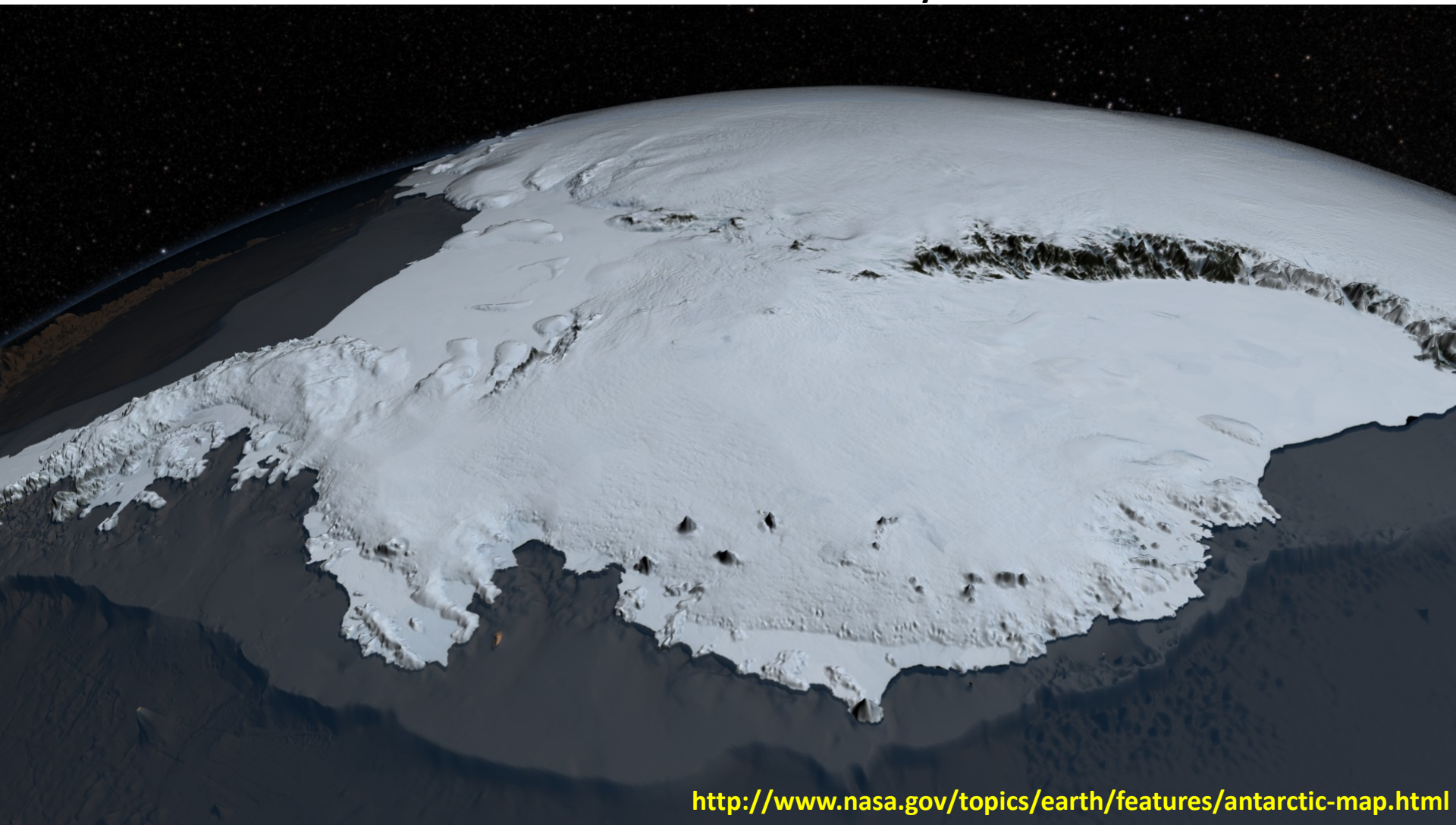
--Less than 2% of continent is snow and ice-free
--Biodiversity very limited due to harsh conditions
--Clear differences between East Antarctica and the Antarctic Peninsula

After the first visits to Antarctica in the 1800s, it was thought to be devoid of life

Now know the microbial community is quite diverse, but very little known

Bulk of microbes (~99%, especially bacteria) on planet has never been cultivated

The rest known as 'microbial dark matter' but numerically dominate in most environments



http://www.nasa.gov/topics/earth/features/antarctic-map.html

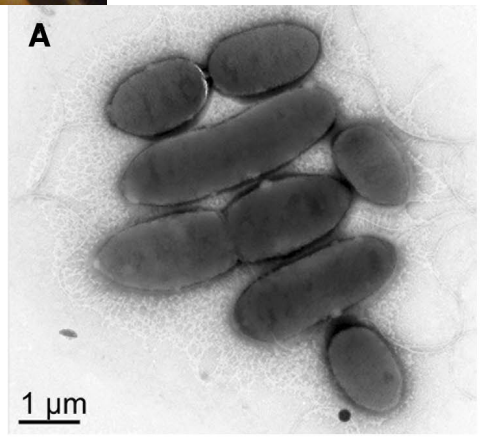
Cold-active bacteria have been cultured from an ice tunnel at the South Pole

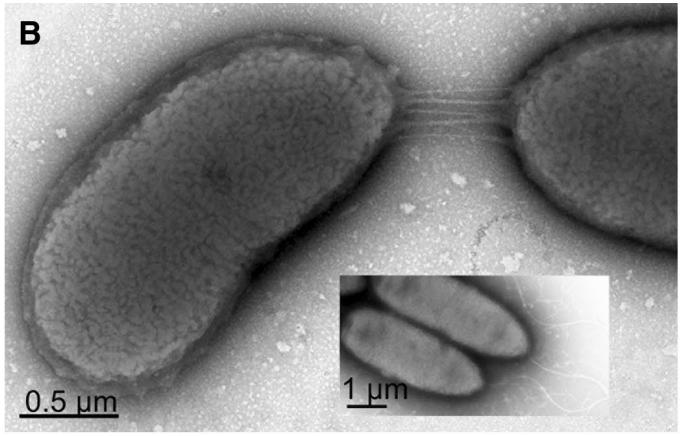
Active in summer when temperatures rise to > -20 °C

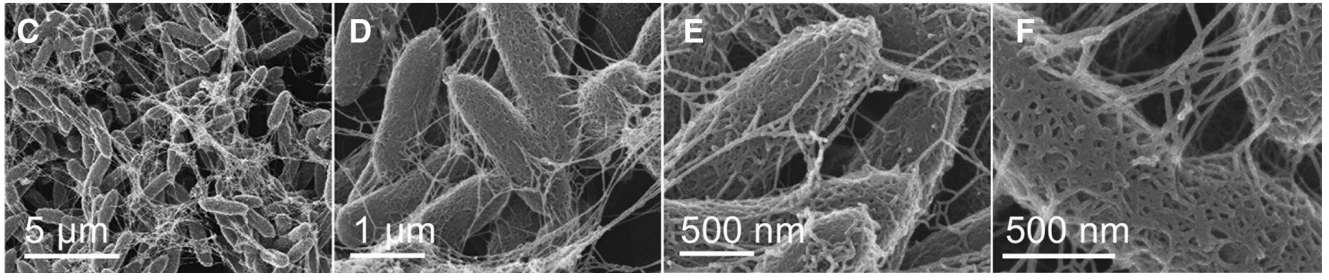
Shows life possible in ultra-cold conditions

Grows faster at cold rather than warm temperatures

Madigan et al. (2017)
Extremophiles

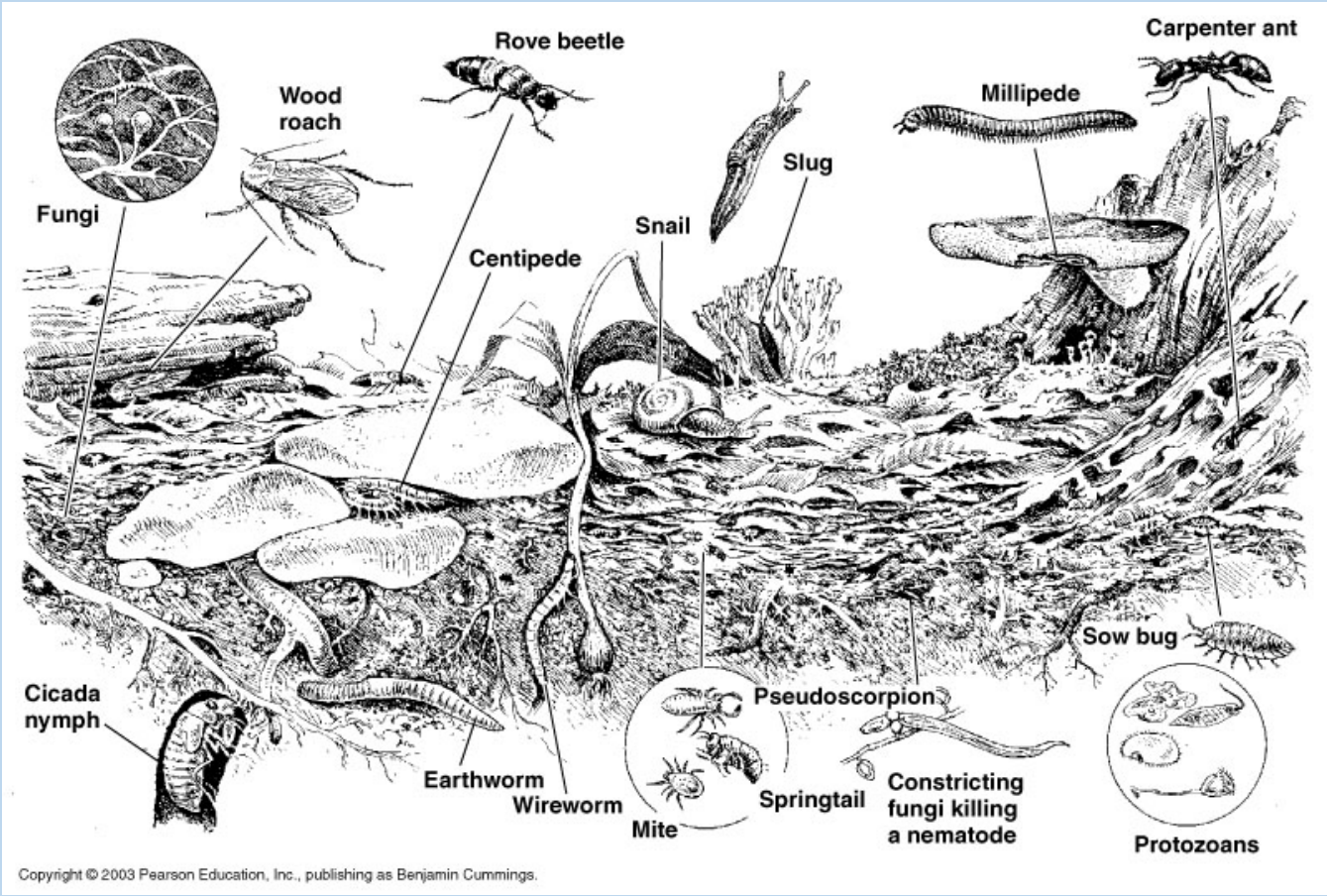






What is a soil versus just dirt?

Soil includes minerals, water, gases, and organic matter
It provides a substrate for plants and thousands of organisms including bacteria, fungi, inverts and vertebrates



Soil Processes

- Parent material
- Climate
- Vegetation
- Topography
- Age

Parent Material

Granite (igneous rock): mineral content includes Al^+, Fe^+, Ca^+, K^+, Mo^+ (molybdenum)

--provides diverse nutrients to vegetation

Serpentine (also igneous): mineral content is Cr (chromium), Mg^+, Ni^+ in high concentrations

--limited nutrients = limited plant growth

Weathering

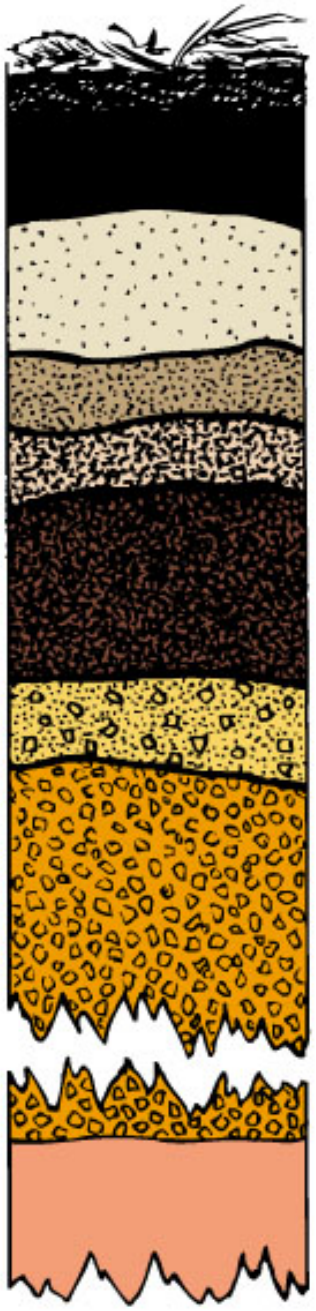
--can be physical or chemical

--physical includes freeze/thaw, scouring by wind and sand to break down rock

Physical weathering: exfoliation from freeze/thaw

Soils also have structure

Horizon thickness and depth dependent on water percolation and soil texture



O_i O_a surface litter

A mineral soil

E zone of leaching (eluviation)

BA/BE

B zone of accumulation (illuviation)

BC

C weathered parent material

R unweathered parent material

Good review of soil microbiology in Antarctica:

Lambrechts et al. 2019. Uncovering the cultivated majority in Antarctic soils: toward a synergistic approach. *Frontiers in Microbiology* 10: doi:103389/fmicb.2019.00242

Antarctic Soils

In East Antarctica, most soil is poorly developed, barren, dry, and low in nutrients

Extreme conditions allow only algae, mosses and lichens to grow

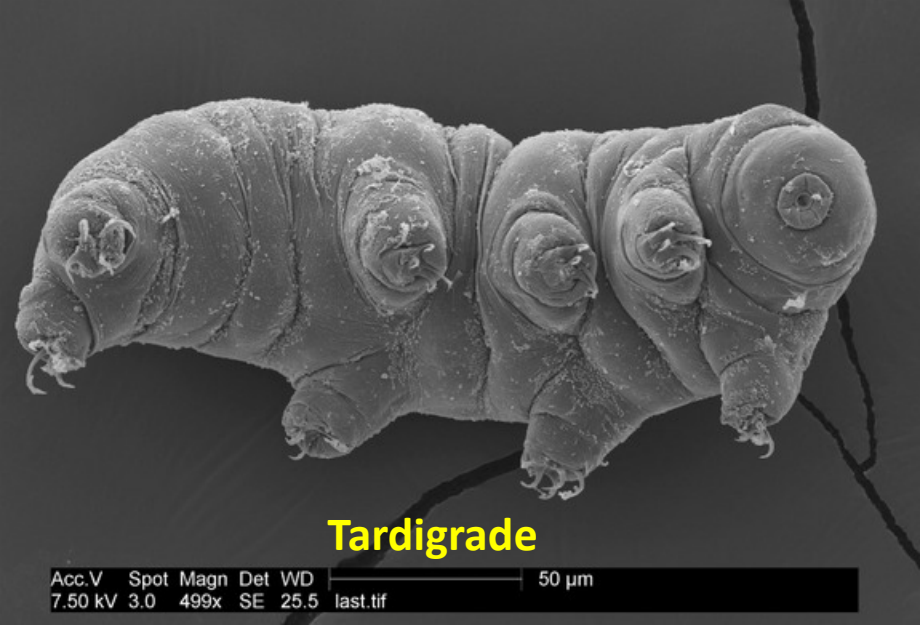
Organisms within soils are limited to bacteria, fungi, protozoa, and some tardigrades, nematodes, and mites

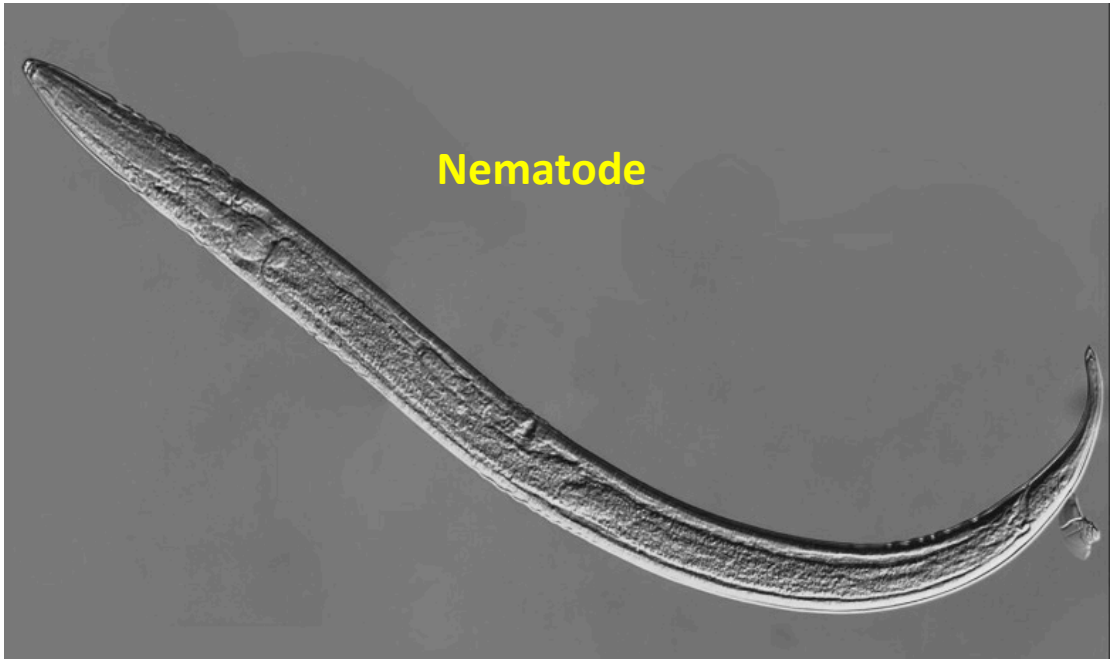
Many different soil types have been defined in Antarctica:

Gelisols: permafrost-affected soils

- **Histels: organic soils underlain with permafrost**
- **Turbels: cryoturbated (mixed layers due to freeze-thaw action) mineral soils underlain with permafrost**
- **Orthels: non-cryoturbated mineral soils**

http://www.landcareresearch.co.nz





http://www.livescience.com/

Arthropoda: springtails and mites

https://www.units.miamioh.edu/


SOUTHERN OCEAN
SOUTHERN OCEAN
SOUTHERN OCEAN
KONG HAKON VII HAV
South Orkney Is
Signy (UK)
Antarctic Circle 66°34'S
South Shetland Is
ANTARCTIC PENINSULA
WEDDELL SEA
Halley (UK)
Palmer (USA)
Rothera (UK)
Alexander I.
PALMER LAND
RONNE ICE SHELF
BELLINGSHAUSEN SEA
90°W
Peter I Sy
ELLSWORTH LAND
AMUNDSEN SEA
WEST ANTARCTICA
Transantarctic Mountains
MARIE BYRD LAND
ROSS ICE SHELF
McMurdo (USA)
ROSS SEA
VICTORIA LAND
TERRE ADÉLIE
GEORGE V LAND
OATES LAND
DRONNING MAUD LAND
COATS LAND
EAST ANTARCTICA
South Pole
Amundsen-Scott (USA)
ENDERBY LAND
KEMP LAND
MACROBERTSON LAND
PRINCESS ELIZABETH LAND
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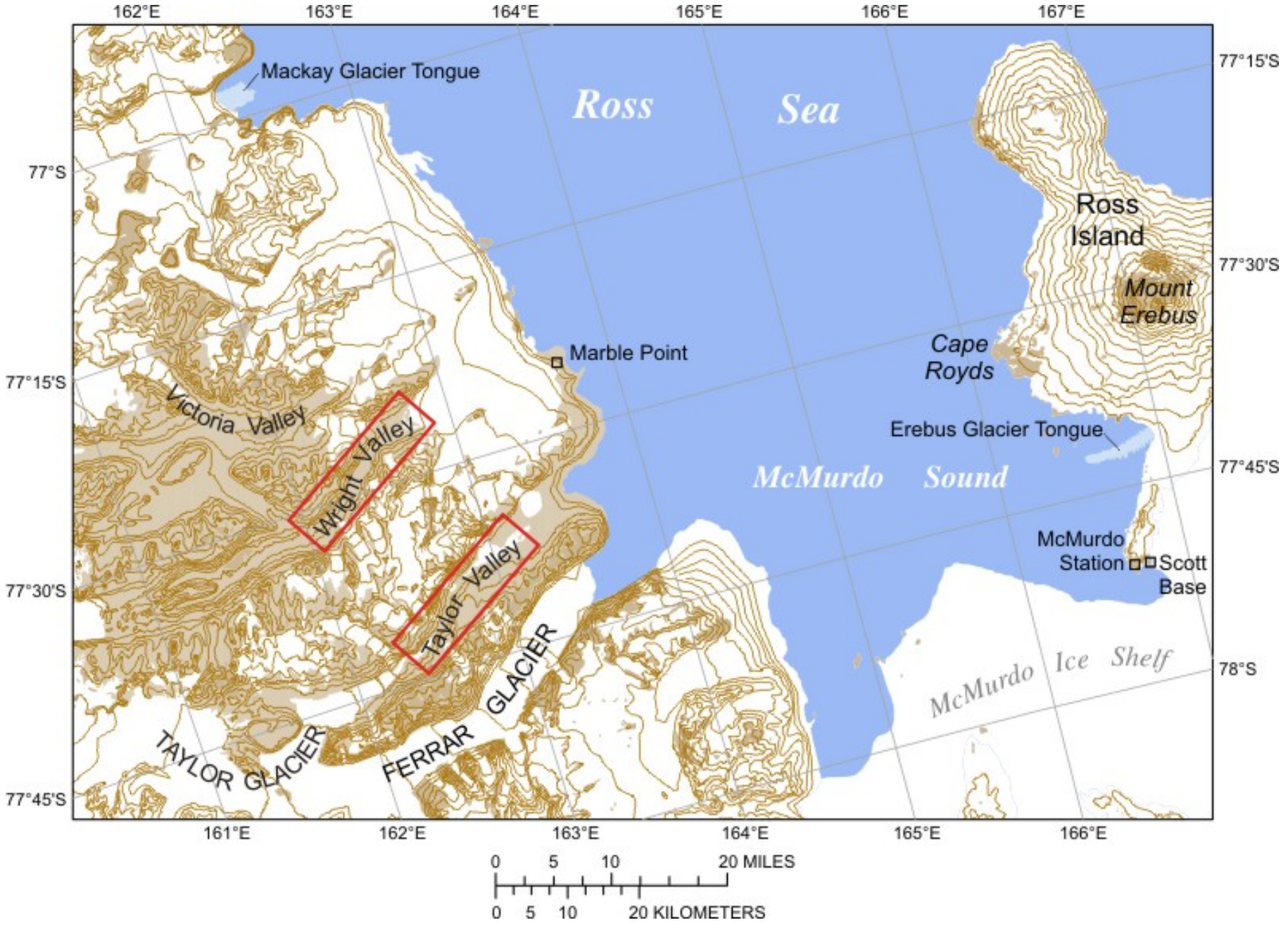
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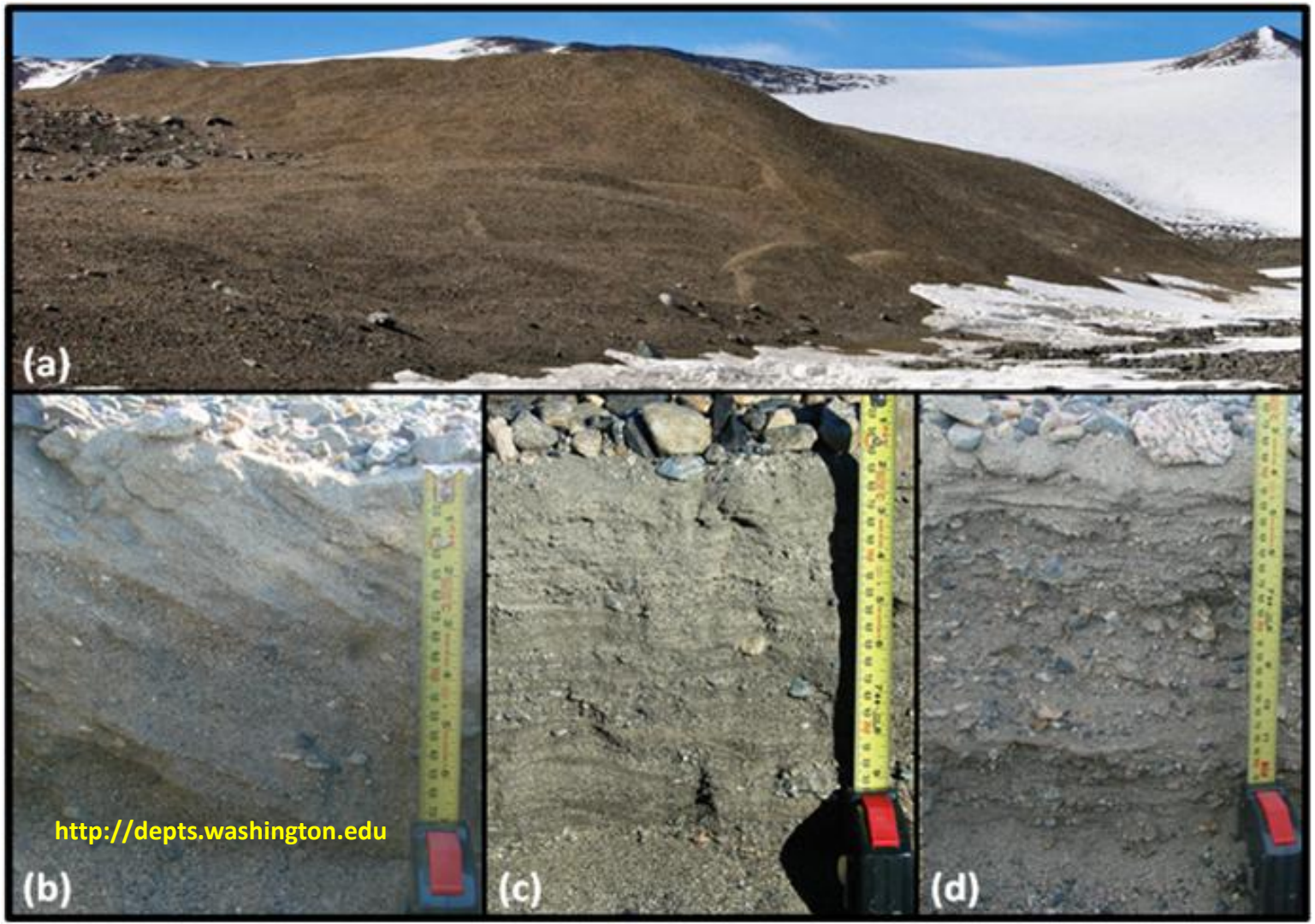
161°E
Mackay Glacier Tongue
Ross Sea
Ross Island
Mount Erebus
Cape Royds
Marble Point
Victoria Valley
Wright Valley
Taylor Valley
Erebus Glacier Tongue
McMurdo Sound
McMurdo Station
Scott Base
McMurdo Ice Shelf
TAYLOR GLACIER
FERRAR GLACIER
0 5 10 20 MILES
0 5 10 20 KILOMETERS

Many soils in the Dry Valleys are poorly developed and formed from fluvial activities in the past

Can be millions of years old, but still have no structure



Antarctic Peninsula

Maritime environment, lower latitude, warmer temperatures

More moisture, with 20-100 cm of precipitation per year, much of it as rain

More moisture means more organic content to the soil, more horizon development with drainage

More plants, inverts, overall higher biodiversity in soils than in East Antarctica

Many different soil types have been described from this region

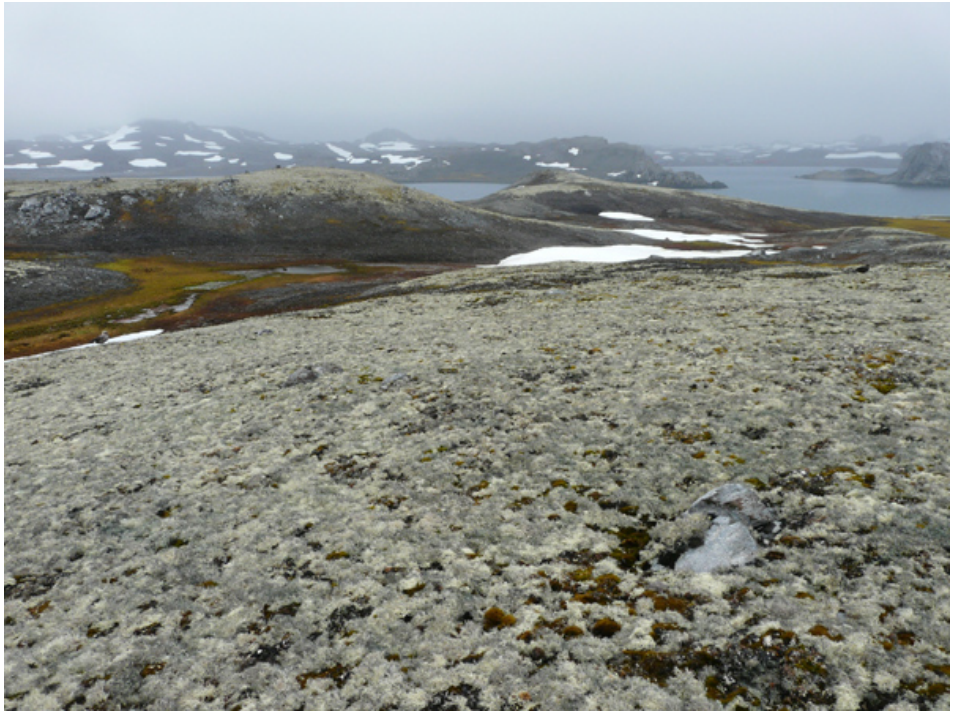


Fig. 12.5 Soils of Cierva Point, including a Lithic Cryosaprists (CP09, *upper left*), Typic Gelorthents (CP10, *upper right*; CP12, *middle-left*; CP19, *lower left*), and a Typic Humigelepts (CP16, *middle-right*)

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)

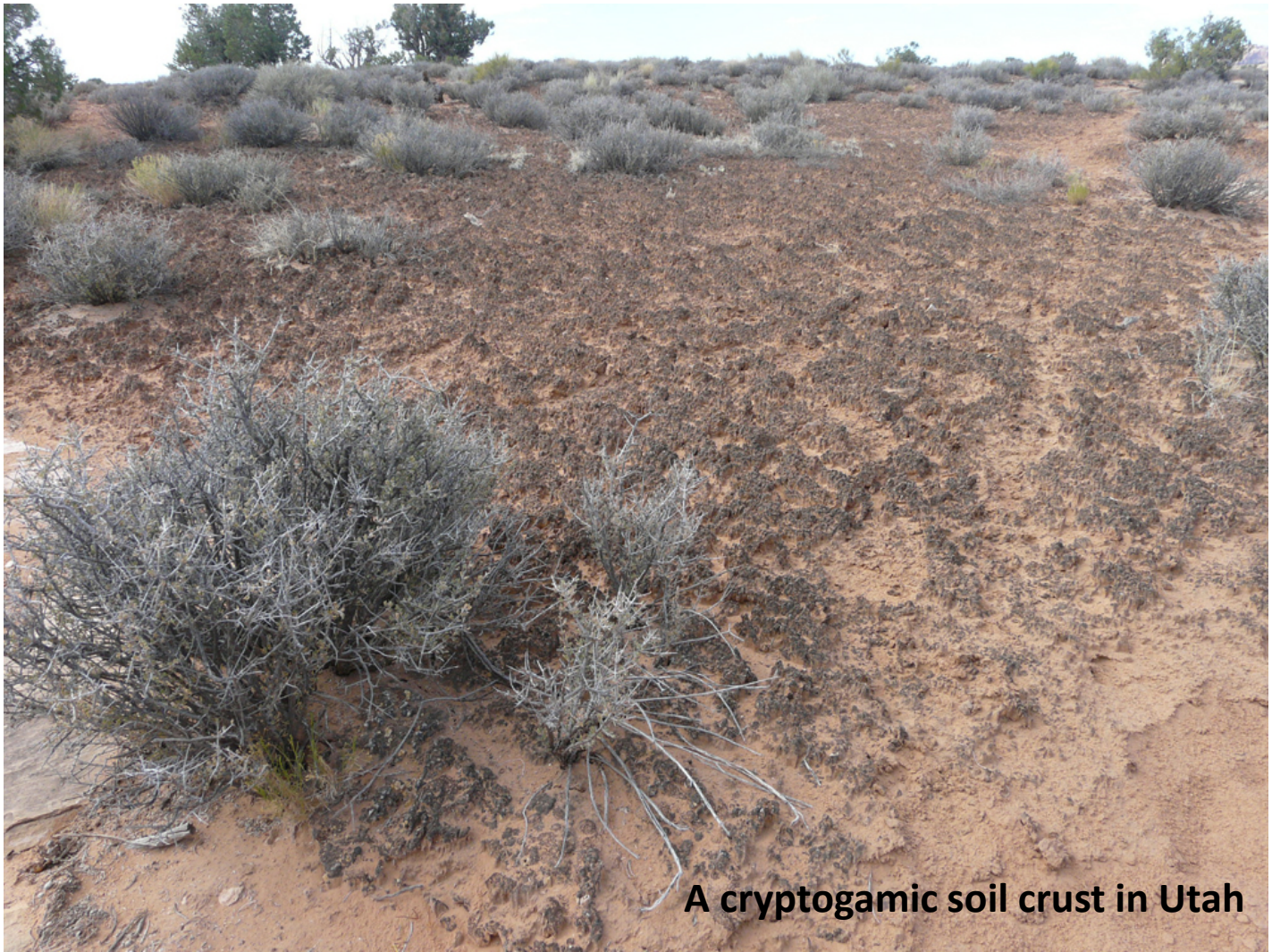
Antarctic Plants and Invertebrates

Current estimates of numbers of species

PLANTS	Sub-Antarctic Islands	Maritime Antarctica	Continental Antarctica
Flowering plants	56	2	0
Ferns and relatives	16	0	0
Mosses and relatives	~400	~100	~30
Lichens	~300	~150	~125
INVERTEBRATES			
Millipedes (Myriapoda)	3	0	0
Mites (Acari)	52	24	21
Flies (Diptera)	44	2	0
Springtails (Collembola)	92+	?	24
Crustaceans (Crustacea)	41	10	14
Snails (Mollusca)	3	0	0
Annelid worms (Oligochaeta)	4	0	0
Nematode worms (Nematoda)	22	40	10
Tardigrades (Tardigrada)	40+	17	6
Rotifers (Rotifera)	102	46	41

Cryptogamic soils

A type of soil crust that develops in arid regions
Includes lichens, fungi, bacteria with high UV tolerance
Allows gas exchange (nitrogen, carbon) and stabilizes the soil



A cryptogamic soil crust in Utah

Lichen Diversity

Types include crustose, foliose, and fructicose

Lichens are fungi and algae in a mutualistic relationship
Algae photosynthesize and/or cyanobacteria can fix nitrogen from air
Fungi provides protection, filaments gather nutrients

Reproduce by either small dry fragments breaking loose and blowing in the wind, carried by animals (birds)
Also fruiting bodies emit spores that must anchor and find algae to form a lichen, most probably die

Lichens can grow in the most extreme environments
The farthest south lichen has been recorded is 87° 09’ S latitude, or about 400 km from the South Pole

Pigments and lichen acids keep them from freezing down to -10 °C
Can still photosynthesize at this temperature
Growth slow, 1 cm/100 yr, or in Dry Valleys 1 cm/1000 yr


Fructicose lichen garden
Livingston Island
About ~150 species of lichens in the AP
Most are crustose

A Fructicose lichen ‘forest’


Foliose lichens
Lagoon Island

Lichen diversity in East Antarctica is more restricted with only about 60 species in Ross Sea area, ~125 continental and ~150 in the AP

Highest diversity is found at abandoned penguin colonies where nutrients from old guano facilitate growth

Biological 'hotspots' in this region


Endolithic lichens

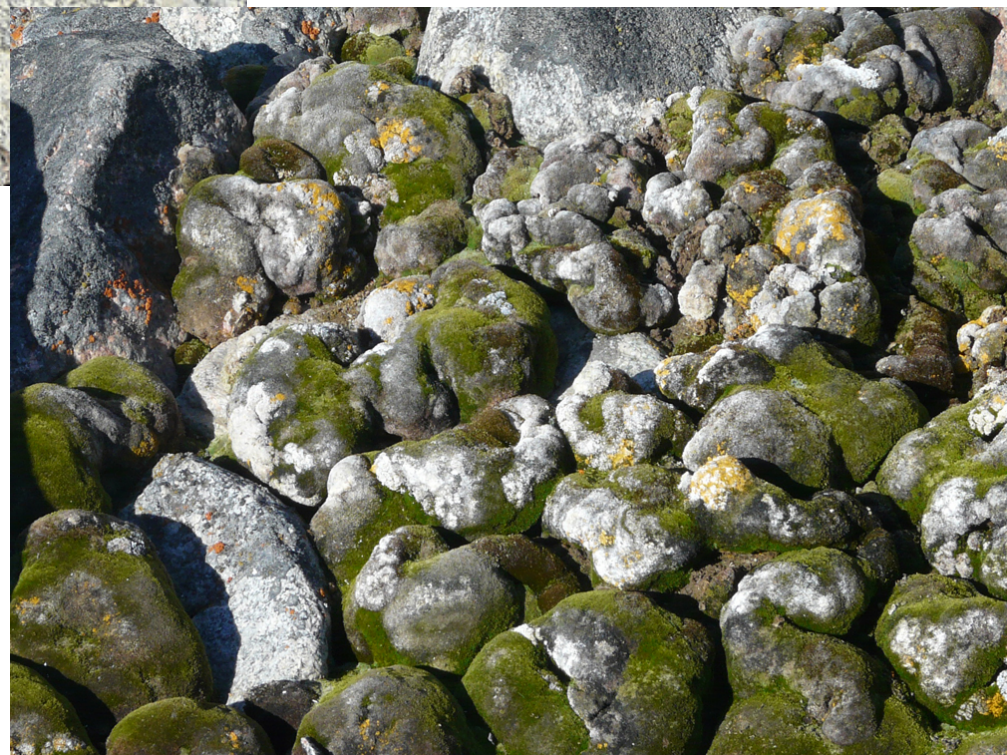
Sampling endolithic lichens in the Dry Valleys

Moss and algae also common in wet or moist areas

~100 species in Antarctica

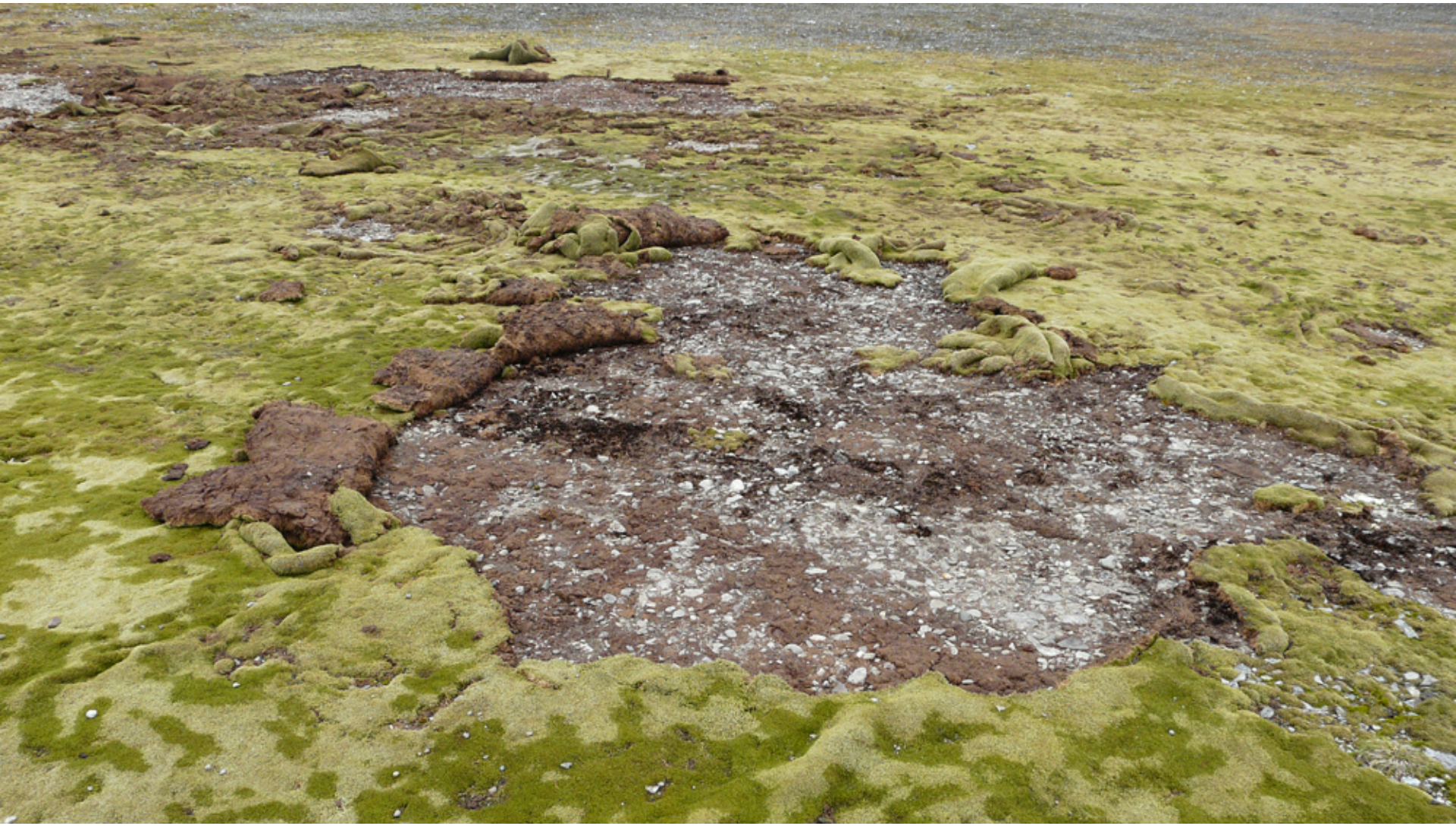
Adapted to cold, dry conditions with densely packed stems to minimize water loss

Snow cover protects them from wind, blowing ice crystals and sand
Also keeps it insulated

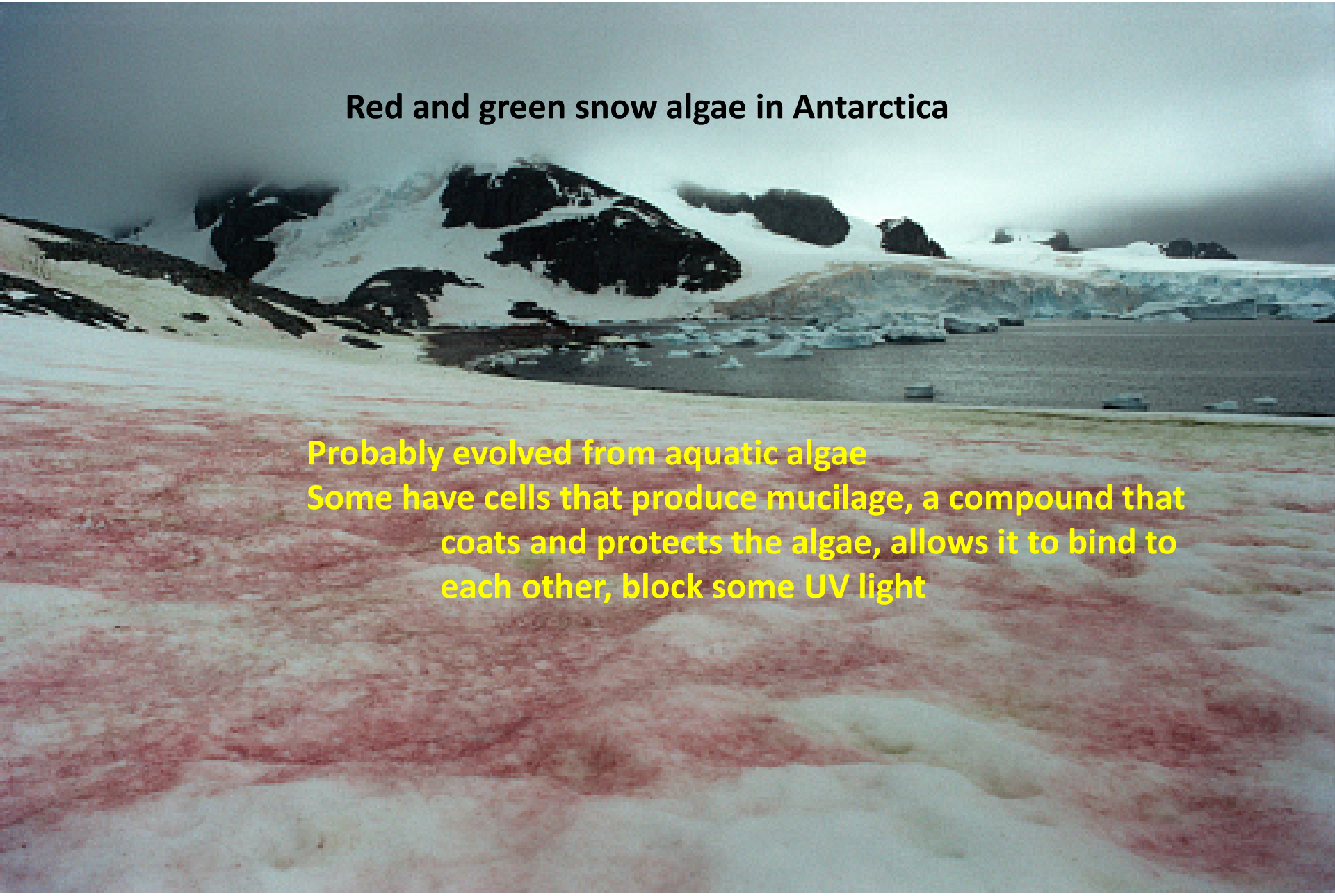


Different pigments indicate diverse photosynthetic physiology

Moss beds can be extensive, especially in the AP, and are sensitive to disturbances




Tracks through moss can last decades



http://www.americanwx.com

There are over 200 species of terrestrial algae in Antarctica, mostly cyanobacteria and green algae

Recent study shows importance of snow algae blooms as a carbon sink

Biomass of algae shifting from snow to land around penguin and seal colonies as warming trend removes more snow in the Antarctic Peninsula

Gray et al. (2020) Nature Comm.
https://doi.org/10.1038/s41467-020-16018-w


Active penguin colonies have a zonation of vegetation from center to edges

Only two flowering plants in Antarctica, both found in the AP
Antarctic grass and a pearlwort

Southern most flowering plants in the world, both wind-pollinated

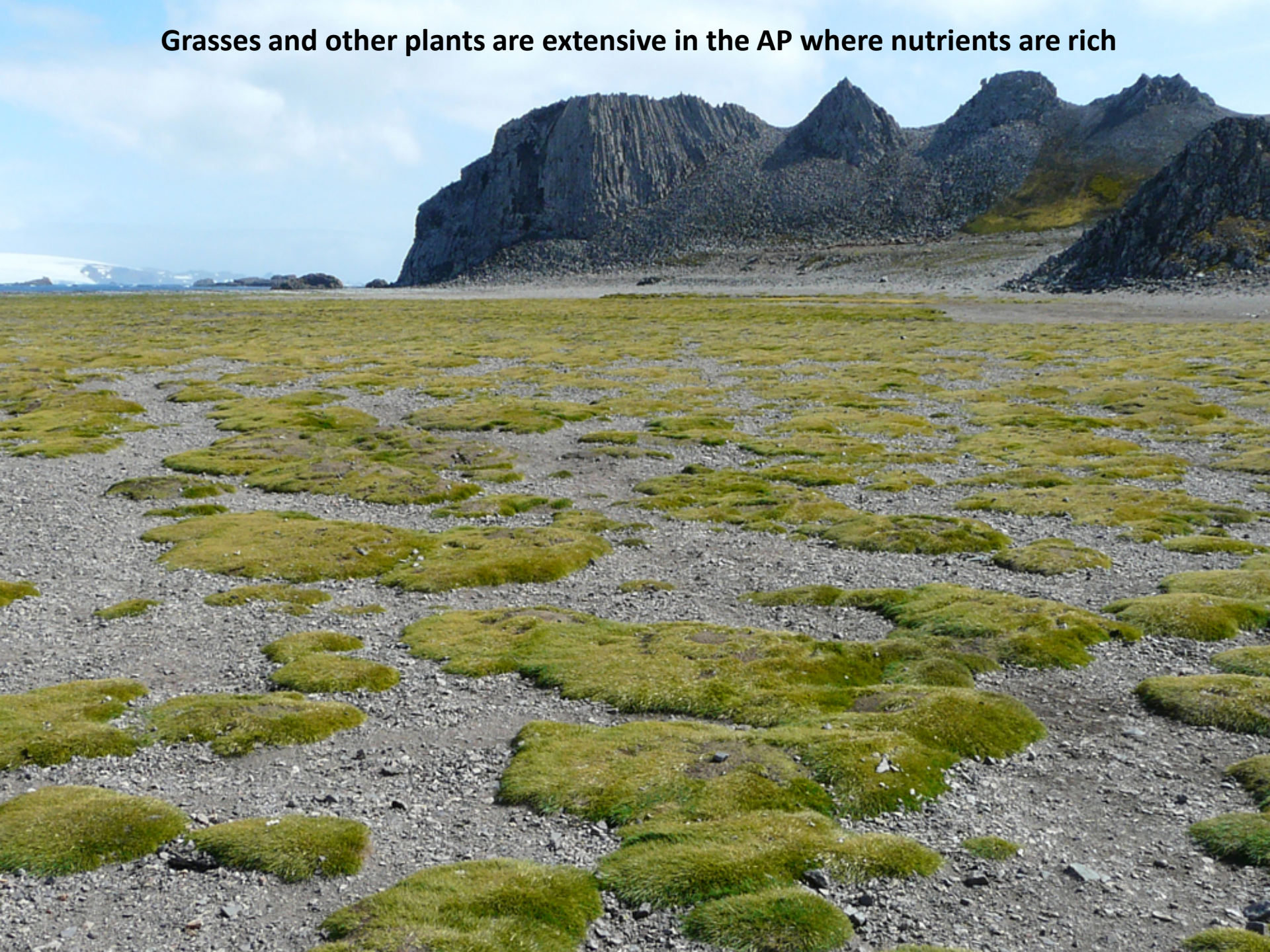
Also found in South America and botanists believe they are relict flora from pre-glacial Antarctica, now re-invading the AP

Deschampsia antarctica

www.grida.no

Colobanthus quitensis

http://www.progettosmilla.it


Grasses and other plants are extensive in the AP where nutrients are rich

Rich growth where penguins used to nest from nutrients in guano

Grasses and pearlwort have been expanding considerably in the AP over the past 20 yrs from warming trend

Soils are undergoing more rapid development, more moisture and weathering

Grasses and other plants are sequestering more carbon in the soil, adding to global carbon cycle more so than before

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Quiz

1. What is the main source of nutrients in most soils?
2. What are gelisols and how do they form?
3. What are the major terrestrial species found in Antarctic soils?
4. What are cryptogamic soils?
5. What are the three types of lichens found in Antarctica?
6. What are the two flowering plants in Antarctica and where are they found?