Antarctic Lakes

See reading on class website at: http://people.uncw.edu/emslies/AntarcticEcology.htm


Freshwater lakes most common

Lakes are found in all ice-free areas of the Antarctic and now many are known to be subglacial, some up to 4 km below the ice sheets

Lakes range from small ponds to large bodies of water, such as those found in the Dry Valleys

Initial research on lakes was in the Dry Valleys, which were discovered during the British Discovery Expedition in 1901-1903

Early focus on algae, algal mats, crustaceans and protozoans, and the physical and chemical environment of the lakes

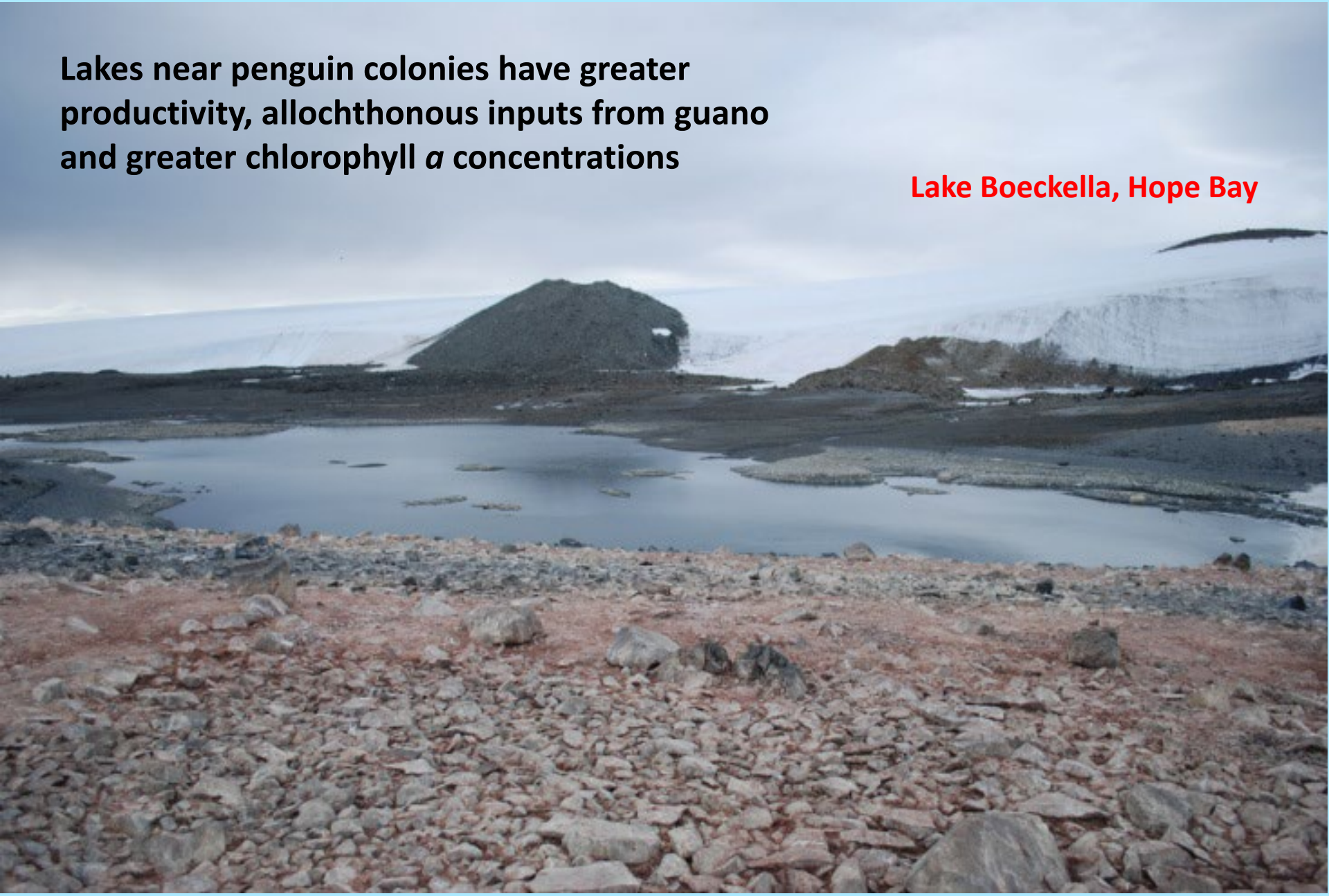
Freshwater lakes

Some started as saline lakes

Salinity varies up to 9 % salt concentration of seawater

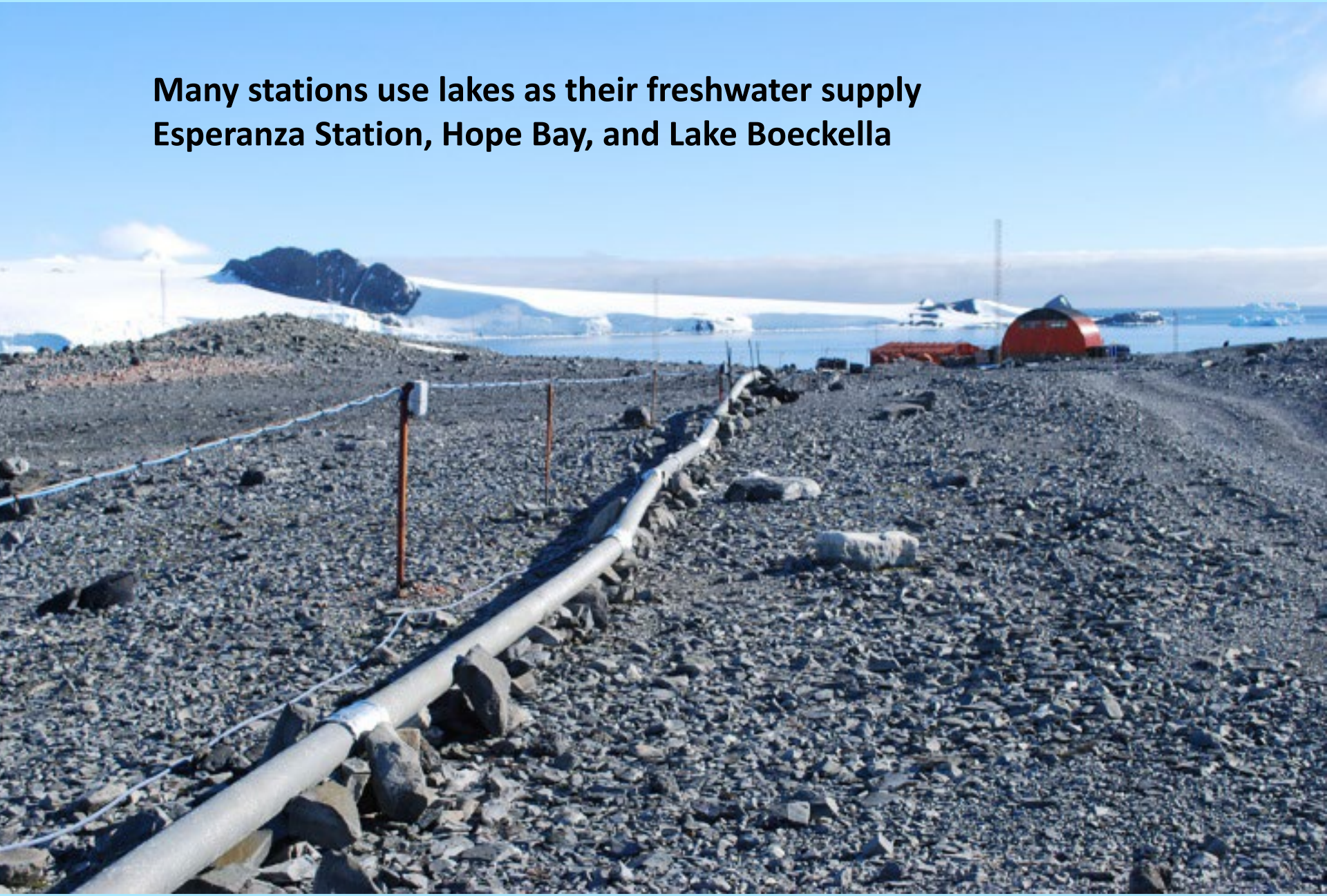

Most are shallow (<50 m depth), deepest is Lake Radok at 350 m
Most are monomictic and oligotrophic to ultra-oligotrophic

Ice cover limits productivity even further, less light penetrates

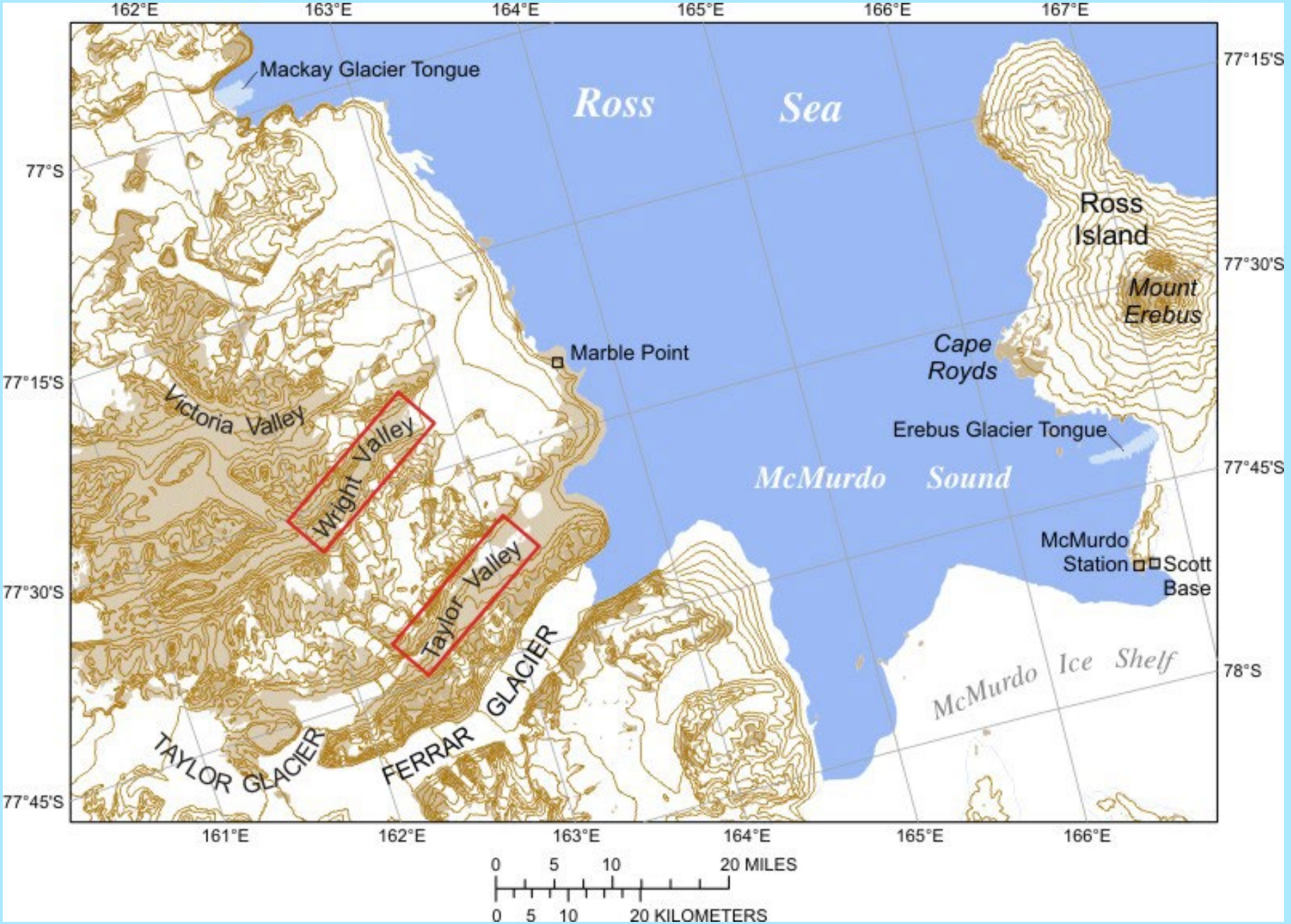

Lakes near penguin colonies have greater productivity, allochthonous inputs from guano and greater chlorophyll *a* concentrations
Lake Boeckella, Hope Bay

Sediment cores provide history of a lake, changes in productivity over time

Many stations use lakes as their freshwater supply
Esperanza Station, Hope Bay, and Lake Boeckella




SOUTHERN OCEAN
SOUTHERN OCEAN
SOUTHERN OCEAN
KONG HAKON VII HAV
South Orkney Is
Signy (UK)
Antarctic Circle 66°34'S
South Shetland Is
Palmer (USA)
Adelaide I.
Rothera (UK)
Alexander I.
ANTARCTIC PENINSULA
PALMER LAND
WEDDELL SEA
Halley (UK)
RONNE ICE SHELF
BELLINGSHAUSEN SEA
AMUNDSEN SEA
ROSS SEA
ROSS ICE SHELF
McMurdo (USA)
Mt Erebus
90°W
90°E
180°
ELLSWORTH LAND
WEST ANTARCTICA
MARIE BYRD LAND
Transantarctic Mountains
VICTORIA LAND
South Pole
Amundsen-Scott (USA)
EAST ANTARCTICA
DRONNING MAUD LAND
COATS LAND
ENDERBY LAND
KEMP LAND
MACROBERTSON LAND
PRINCESS ELIZABETH LAND
WILHELM II LAND
QUEEN MARY LAND
WILKES LAND
TERRE ADÉLIE
GEORGE V LAND
OATES LAND
0 1000 2000
Km
0 200 400 600 800 1000
Miles


162°E
163°E
164°E
165°E
166°E
167°E
77°15'S
77°S
77°30'S
77°45'S
78°S
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

Dry Valley Lakes

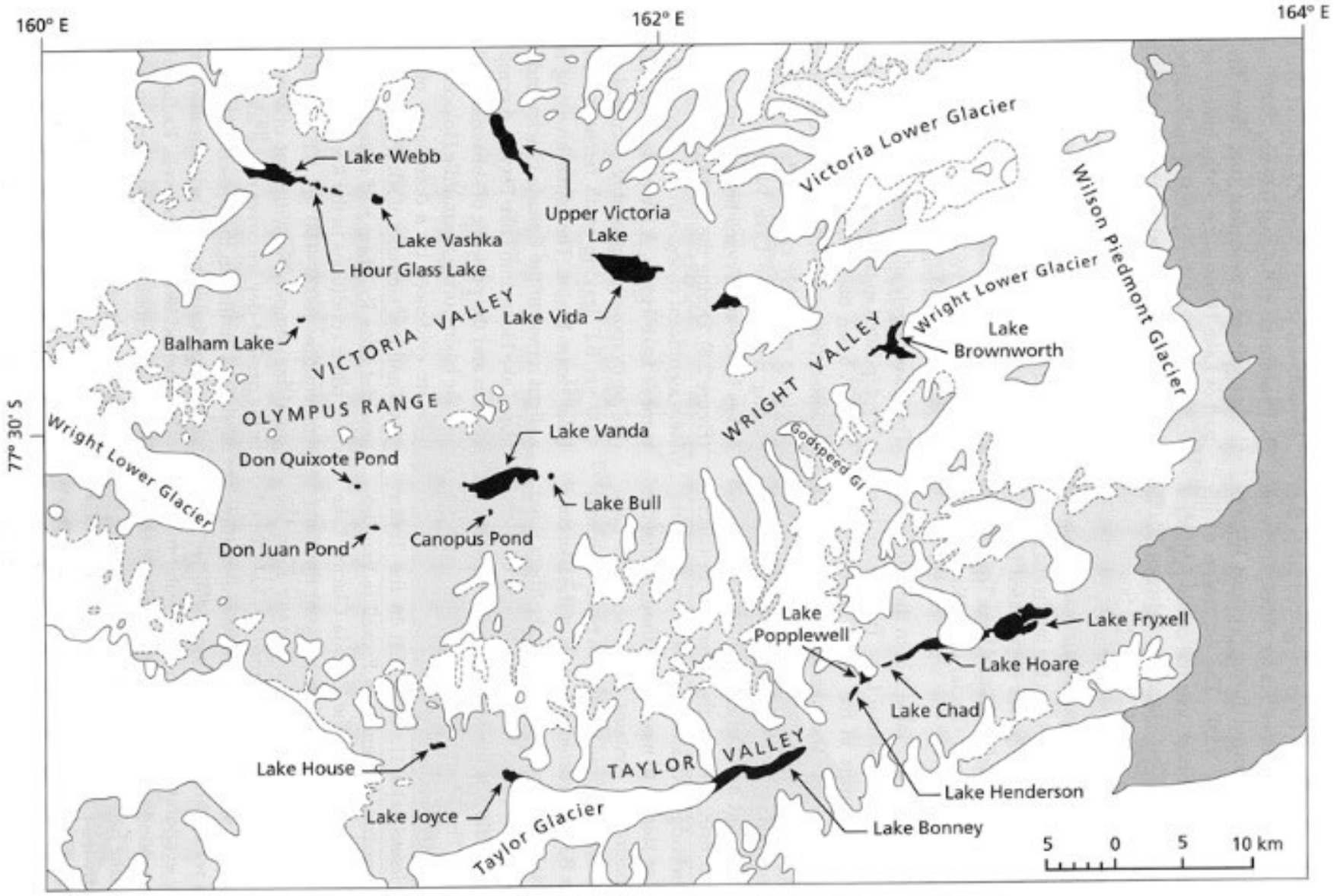
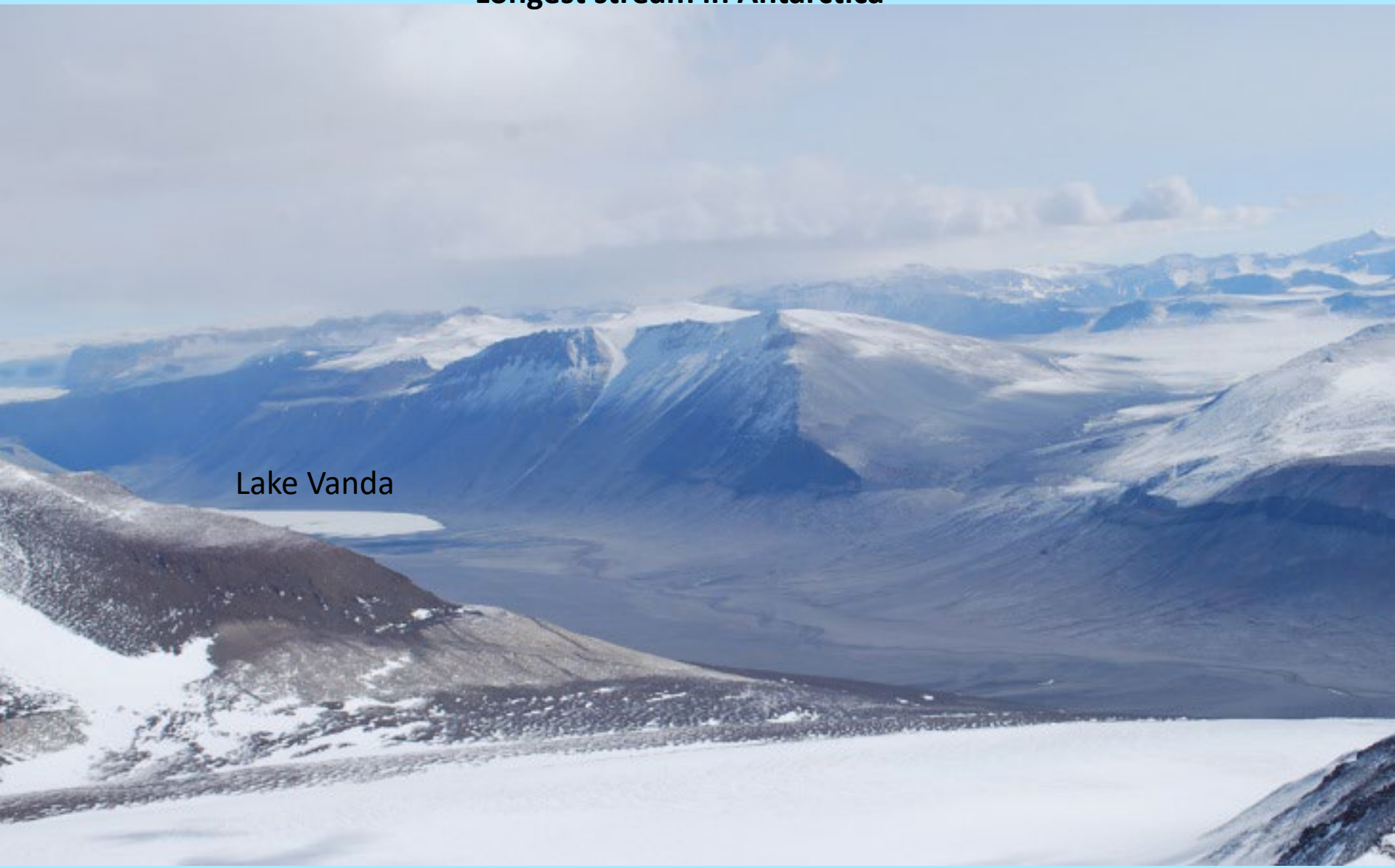


Figure 2.7 A map of the McMurdo Dry Valleys showing major lakes. For more details of lakes see Table 2.1 (freshwater lakes) and Table 3.1 (saline lakes).

From Laybourn-Parry and Wadham. 2014. Antarctic Lakes. Oxford Univ. Press

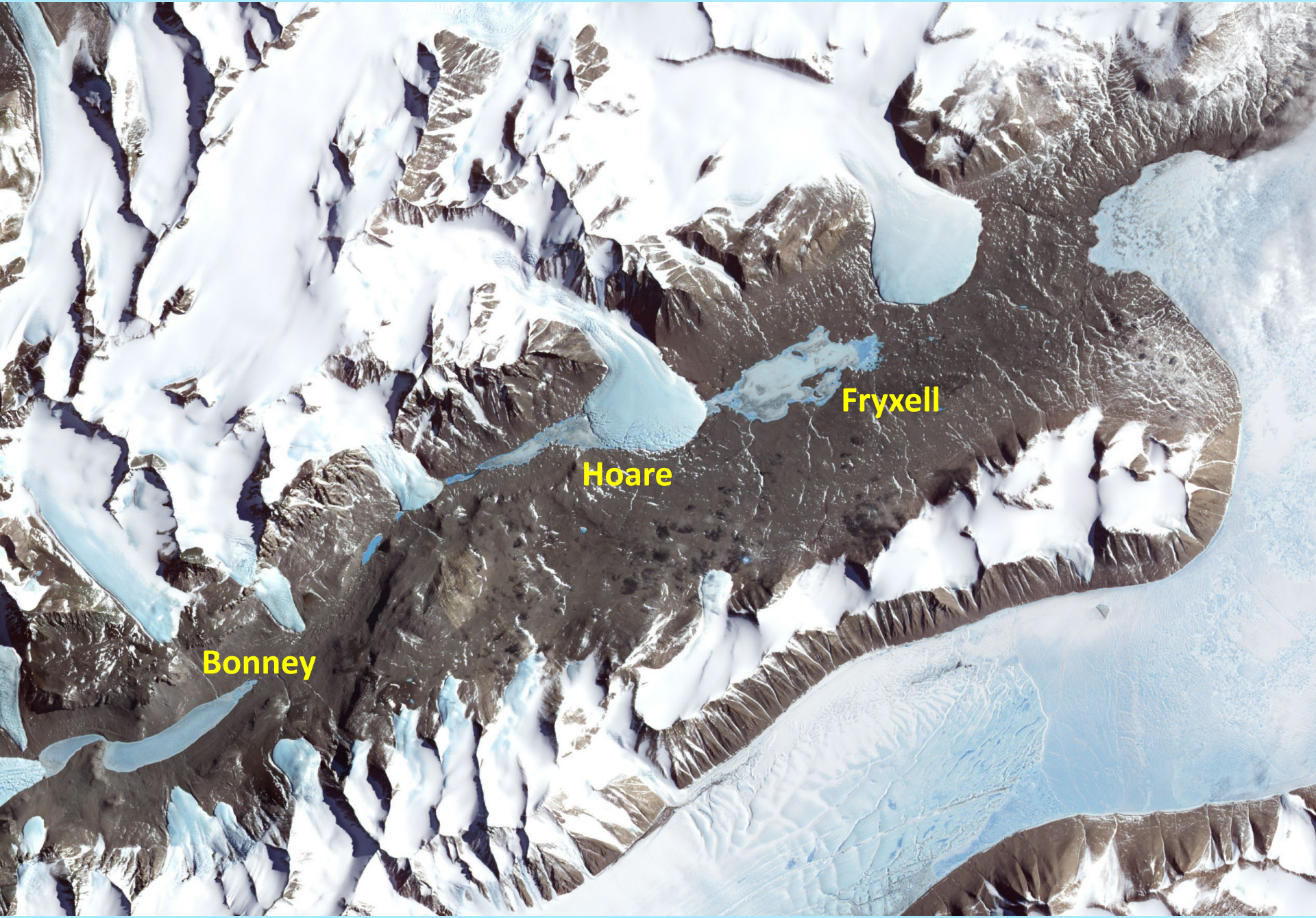
Wright Valley and Onyx River
Longest stream in Antarctica

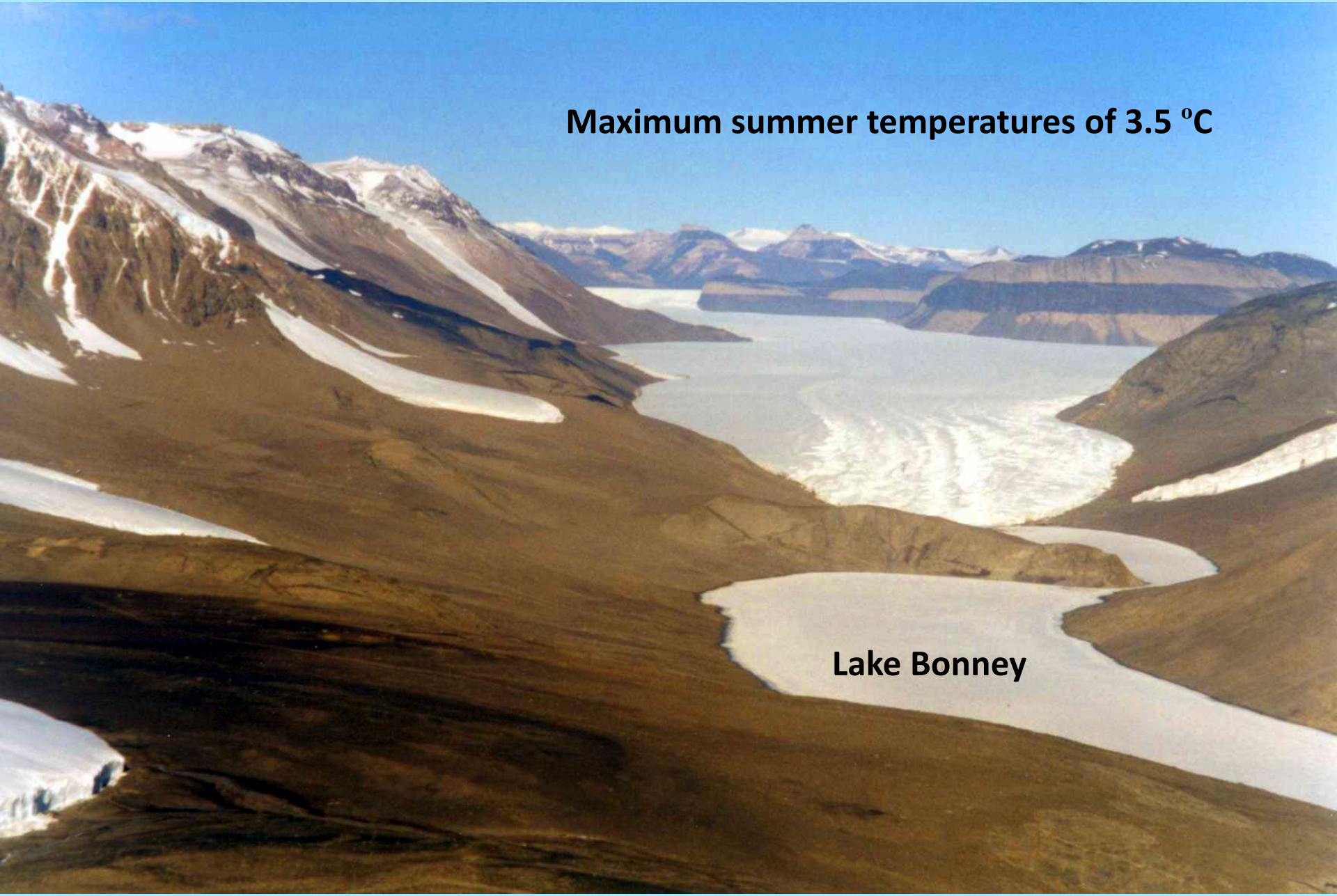


Lake Vanda, Wright Valley

Transparent ice allows more solar radiation, warming below ice
Phosphorus deficient, ultra-oligotrophic and meromictic

Victoria Lake, Victoria Valley


Fryxell
Hoare
Bonney

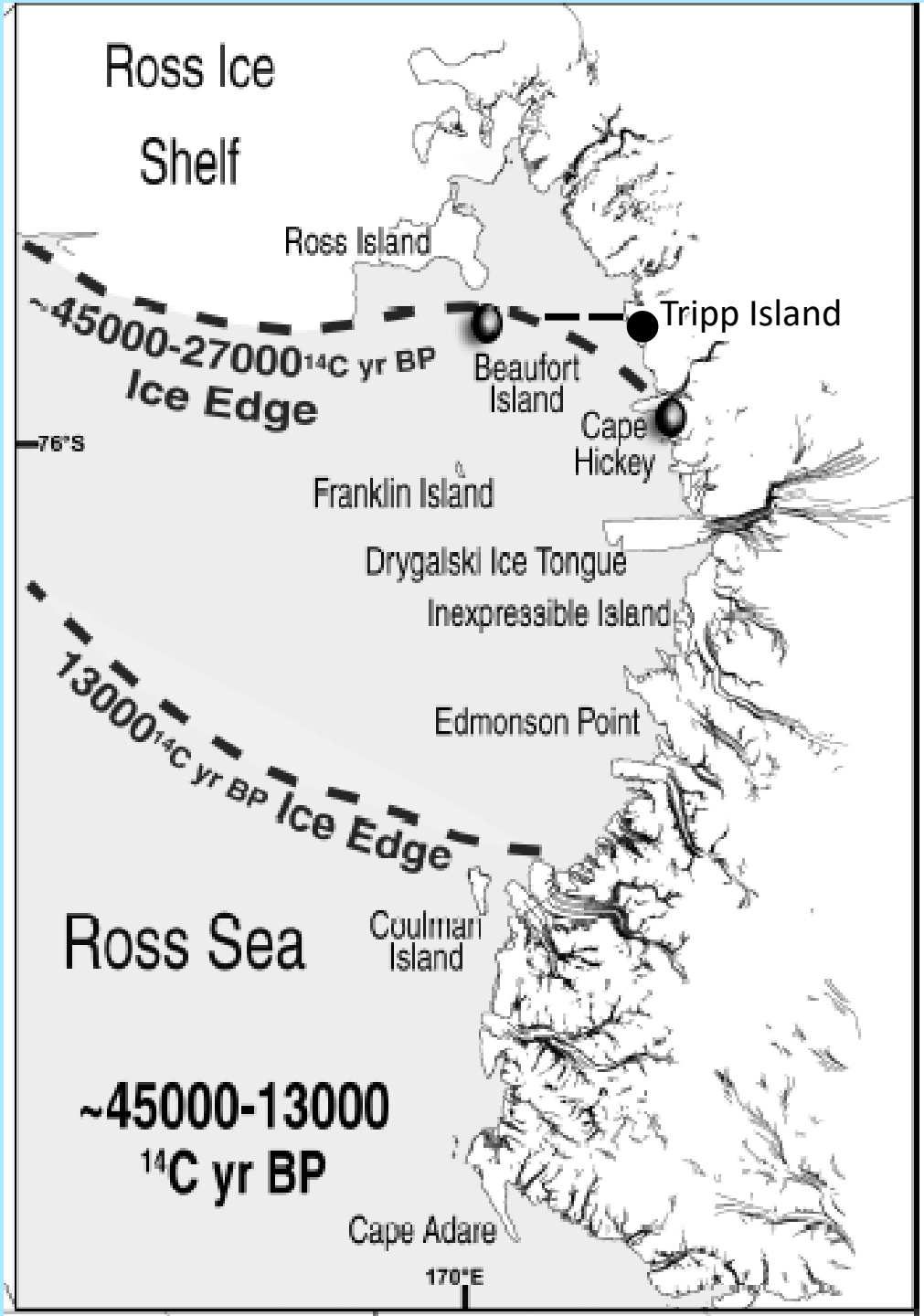

Maximum summer temperatures of 3.5 °C
Lake Bonney

Ice cover on lakes reduces light penetration. At Lake Hoare, which is permanently ice-covered, light penetration is reduced to only 1.7-3.3% of that striking the surface of the ice

Lake temperatures remain consistently low with little or no thermal stratification, especially if ice-covered. Thus, they remain amictic or monomictic with temperature changes of a few degrees C.

Late Pleistocene RIS advances and retreats

Last advance began ~27,000 BP
Farthest north at ~ 20,000 BP
Retreat began ~13,000 BP



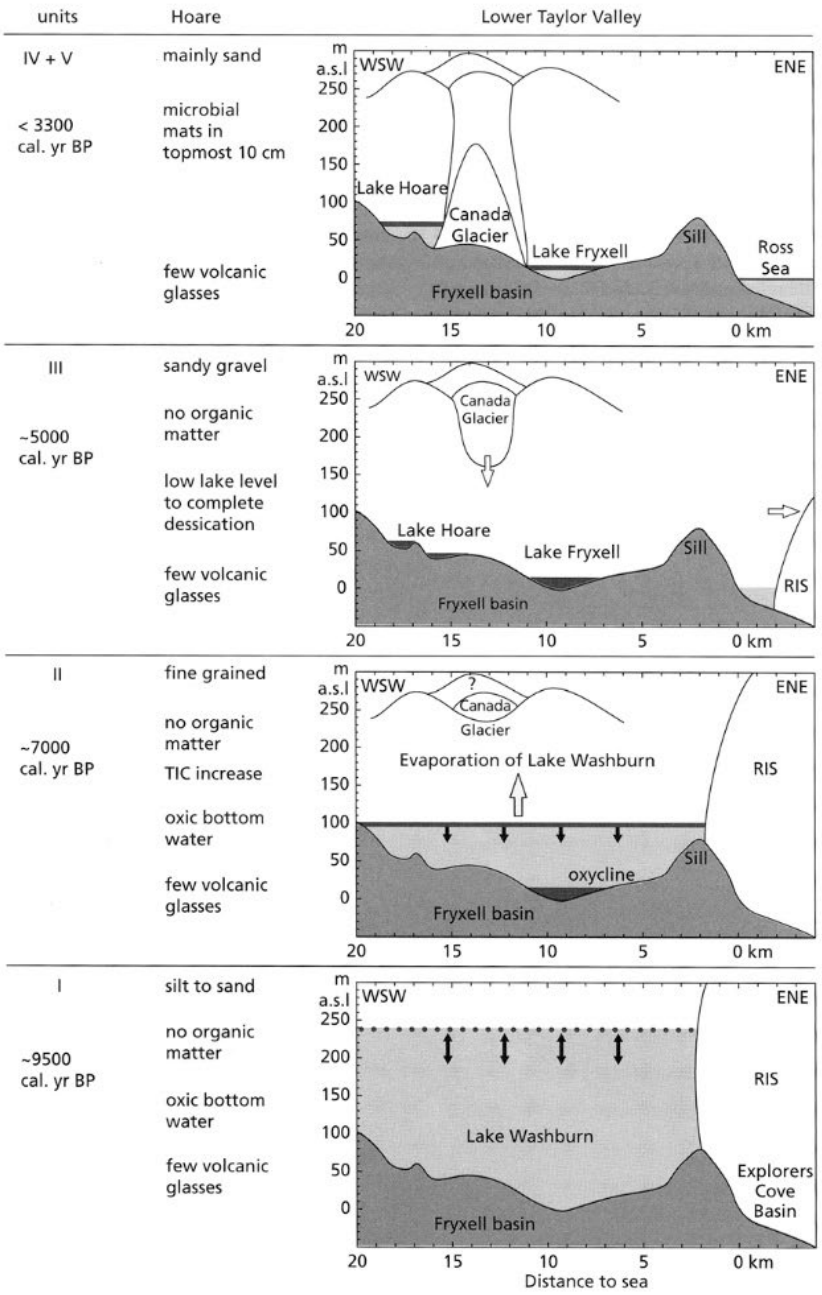
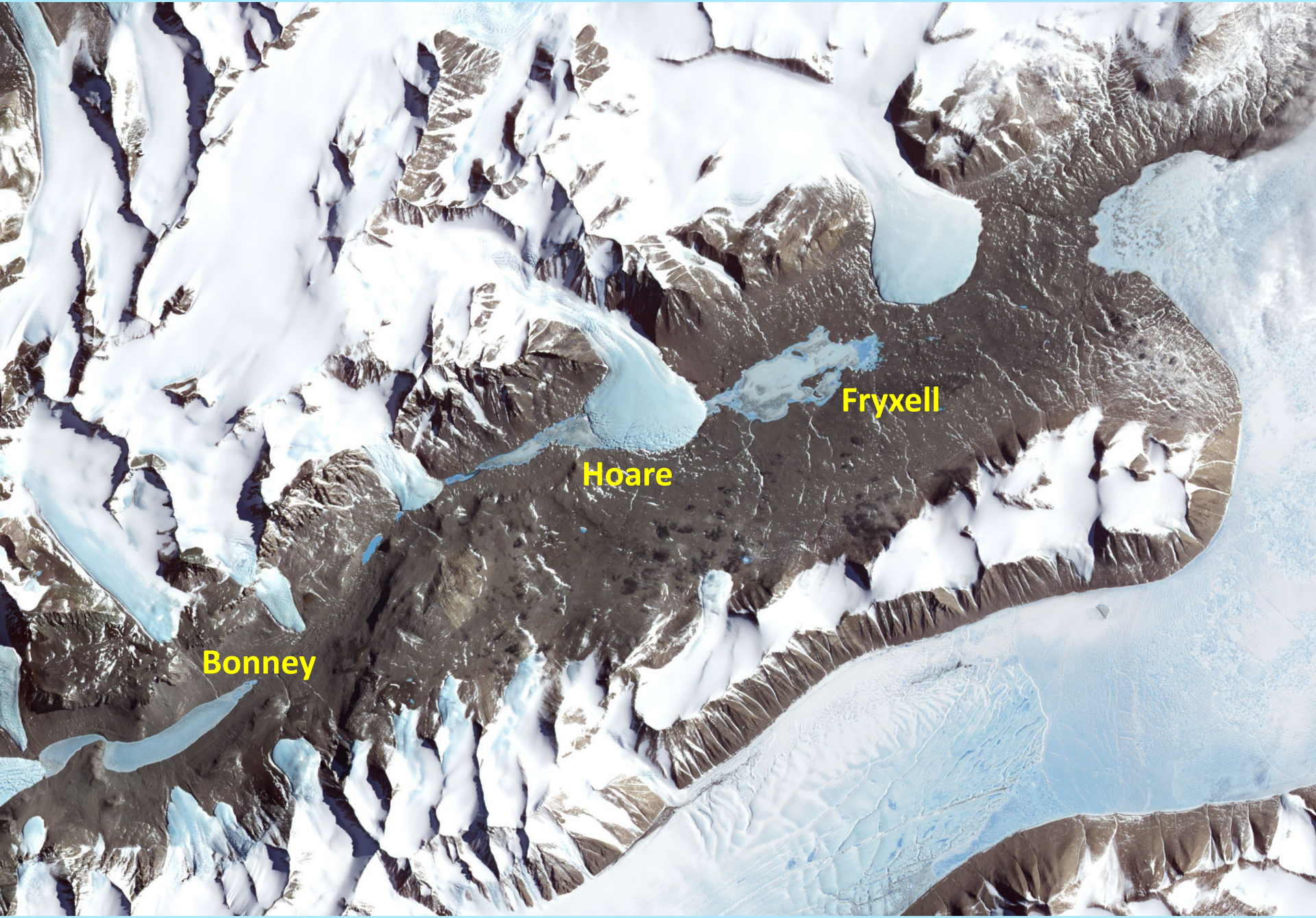


Figure 2.8 A pictorial evolution of Lake Hoare in the Taylor Valley, McMurdo Dry Valleys based on sediment cores. RIS – Ross Ice Shelf. From Wagner et al. (2011) with the permission of Cambridge University Press.

Evolution of Dry Valley Lakes

From core from Lake Hoare and sediments from Fryxell

From Laybourn-Parry and Wadham. 2014. Antarctic Lakes. Oxford Univ. Press


Fryxell
Hoare
Bonney

Biota in freshwater lakes include:

Bacteria
Viruses
Protozoa
Phytoplankton including algae and photosynthetic bacteria
Zooplankton including cladocerans, rotifers, copepods
Cyanobacterial mats in benthos

Antarctic freshwater zooplankton:

Rotifer (Phylum Rotifera)
Cladoceran (*Daphnia*) and copepod (Crustacea)

https://en.wikipedia.org

Fairy Shrimp (*Branchinecta* sp.)

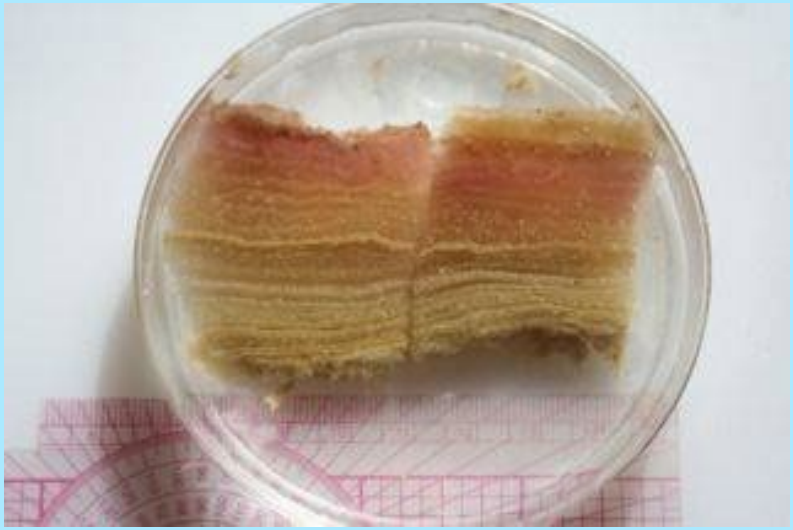
Skua ‘club’

http://huey.colorado.edu/cyanobacteria/about/cyanobacteria.php

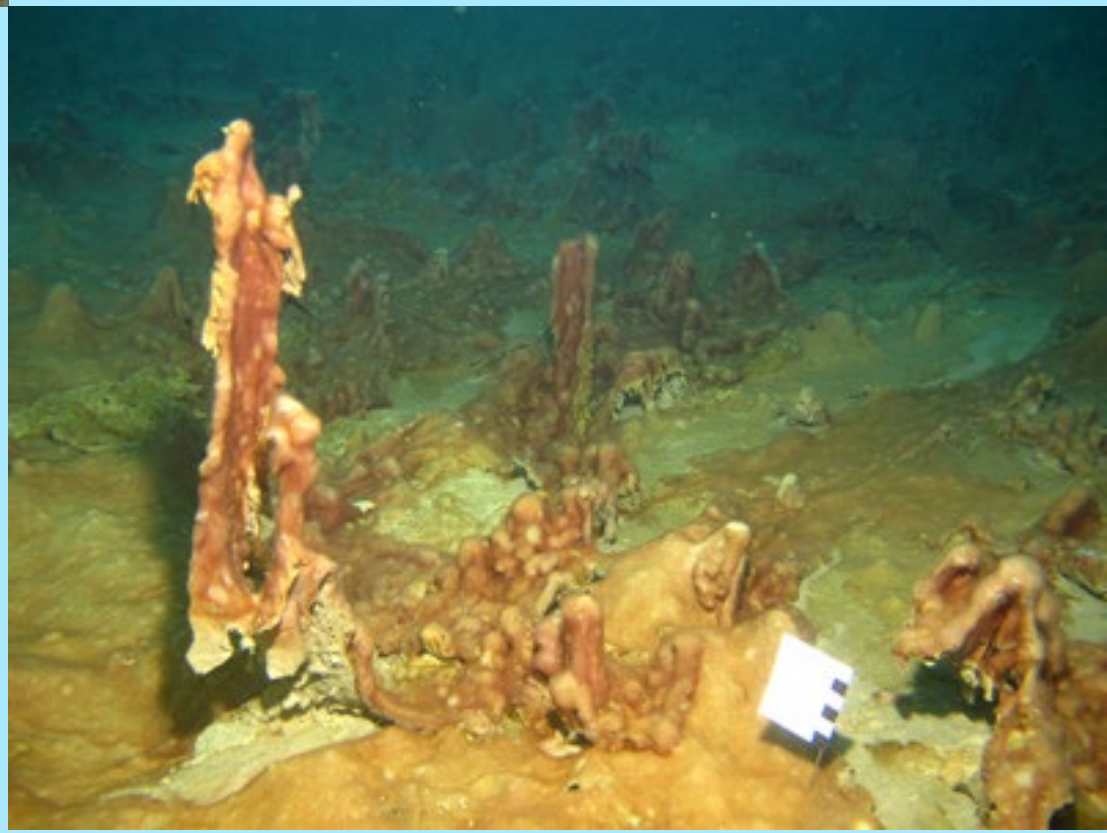
Cyanobacteria are phototrophic bacteria that can fix nitrogen from the atmosphere.

The mats are comprised of cyanobacteria, bacteria, and diatoms and form layers

These mats often occur in extreme and fluctuating environments



http://www.nhm.ac.uk/natureplus/blogs/Antarcticcyanobacteria/2010/12/23/cyanobacterial-mat-communities-in-lake-hoare



Pond on Inexpressible Island

Saline Lakes

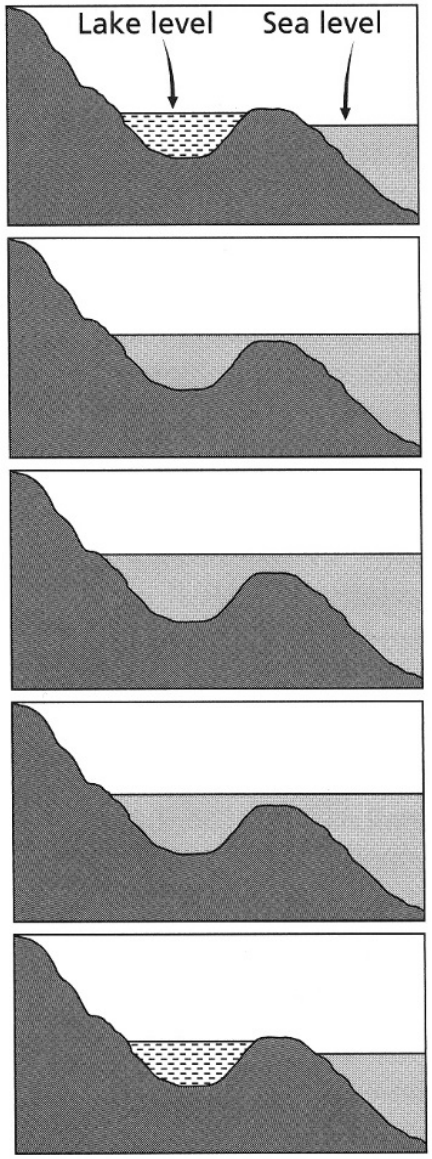
Defined as having salinity >9 %

Usually are closed lakes, inflow but no outflow

Water loss by evaporation, which concentrates the salts over time

Productivity is generally higher in these lakes compared to freshwater lakes

Often meromictic, or seldom mix



Unit 1: Freshwater lake
ca. 13,000–9400 cal yr B.P.
Anoxia: absent

Unit 2: Seasonally isolated marine basin
9400–*ca*.9000 cal yr B.P.
Anoxia: present

Unit 3: Open marine basin
ca. 9000–5700 cal yr B.P.
Anoxia: absent

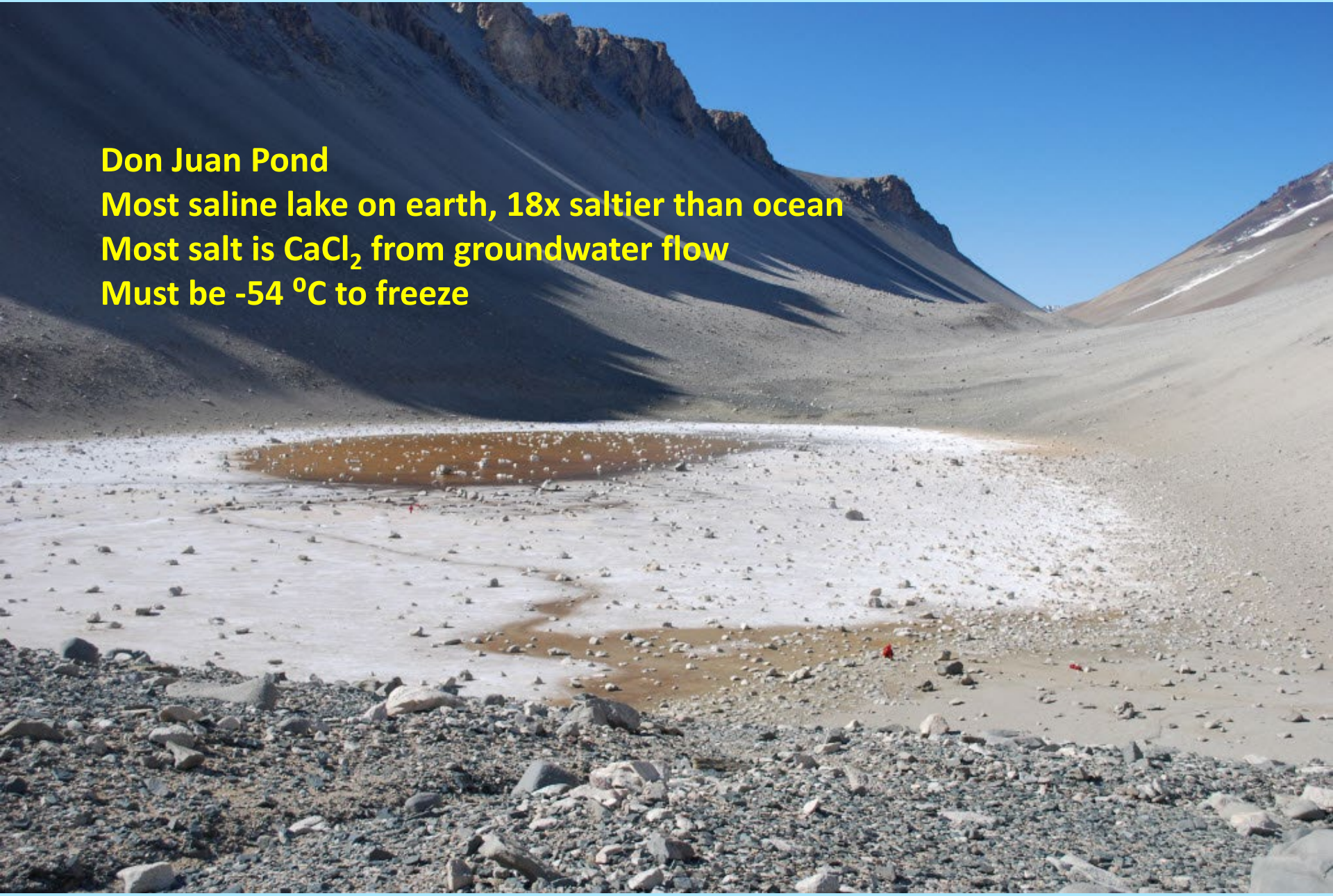
Unit 4: Seasonally isolated marine basin
5700–5100 cal yr B.P.
Anoxia: present

Unit 5, 6: Saline lake
ca. 5100 cal yr B.P. - Present
Anoxia present

From Laybourn-Parry and Wadham. 2014. Antarctic Lakes. Oxford Univ. Press

Plate 8 Arial photograph of a suite of saline lakes in the Vestfold Hills. From the left bottom seaward: Lake Jabs, Club Lake, Deep Lake (salinity X 10 seawater), Lake Stinear, and Lake Dingle. Photo J. Laybourn-Parry. (See Figure 1.13)

From Laybourn-Parry and Wadham. 2014. Antarctic Lakes. Oxford Univ. Press


Don Juan Pond
Most saline lake on earth, 18x saltier than ocean
Most salt is $CaCl_2$ from groundwater flow
Must be -54 ^{o}C to freeze

Meromictic lake with saline, anoxic monimolimnion below a colder, less saline and oxic mixolimnion

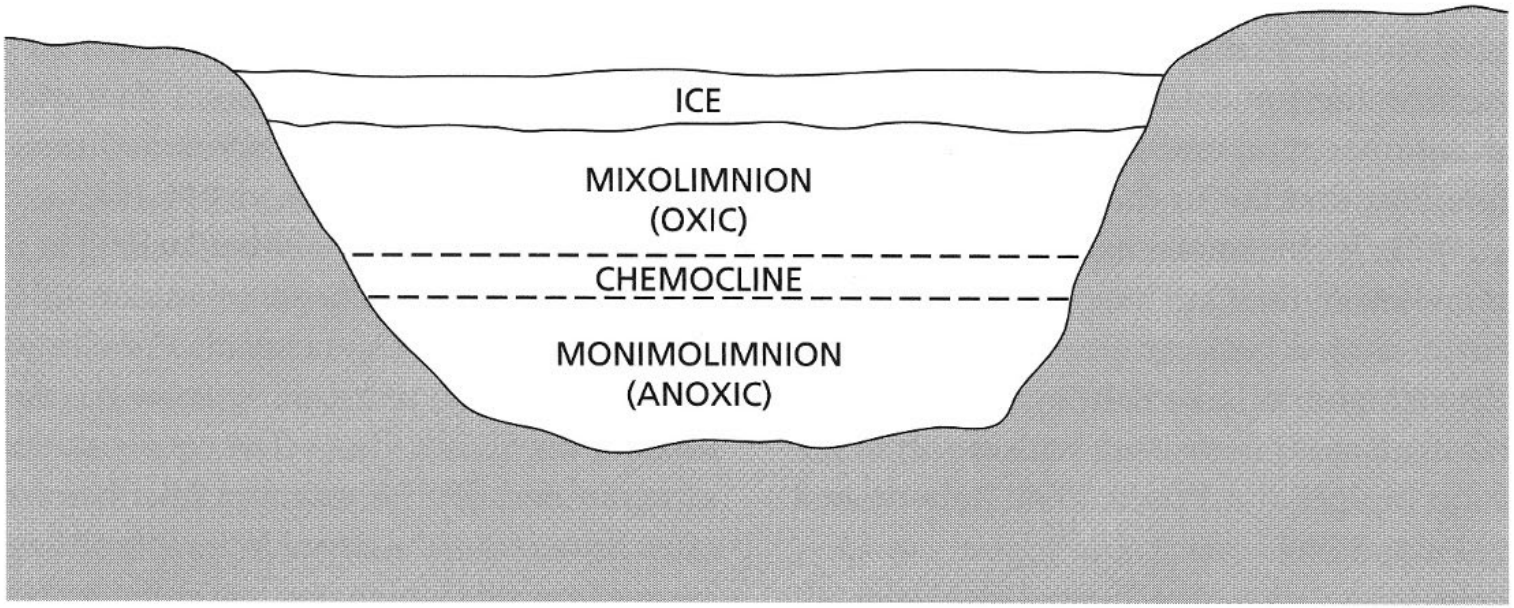
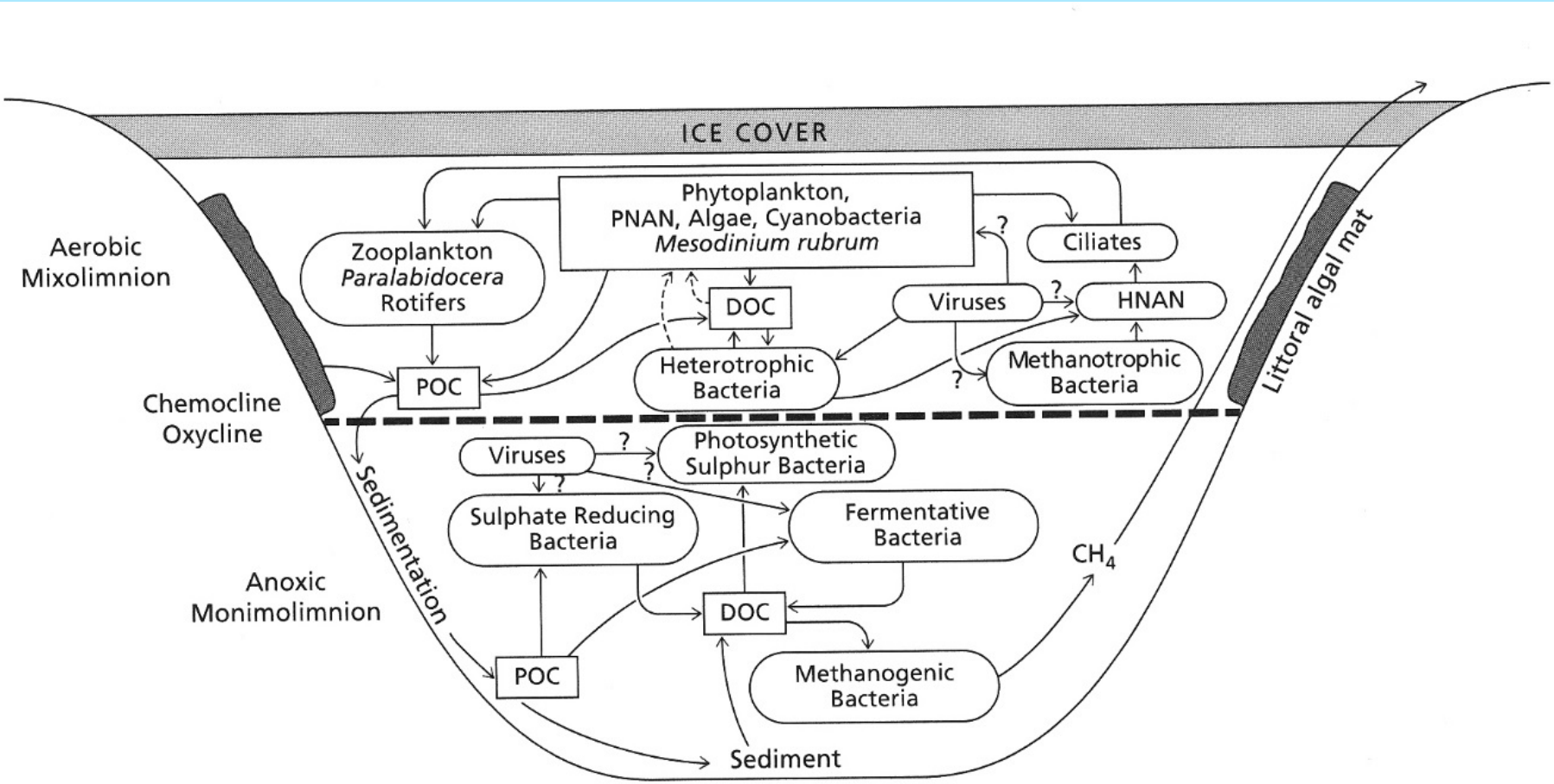


Figure 3.3 A schematic showing the structure of a permanently stratified meromictic lake. The upper mixolimnion encompasses the euphotic zone where the waters are oxygenated. The chemocline is a zone of strong gradients in physical/chemical conditions (temperature, salinity and nutrients). The lower waters or monimolimnion are permanently anoxic.

From Laybourn-Parry and Wadham. 2014. Antarctic Lakes. Oxford Univ. Press



From Laybourn-Parry and Wadham. 2014. Antarctic Lakes. Oxford Univ. Press

Pony Lake, Cape Royds, Ross Island

Freshwater in summer with ice melt
Saline in winter as ice forms

https://sensibleheat.wordpress.com/

Supraglacial Lakes

Range from small ponds to larger lakes several km^2
Usually very shallow, short-lived
Very low in biota
Some are deep, small holes that connect to the sub-glacial hydrological system
Also ice shelf lakes at ablation zone of ice shelves

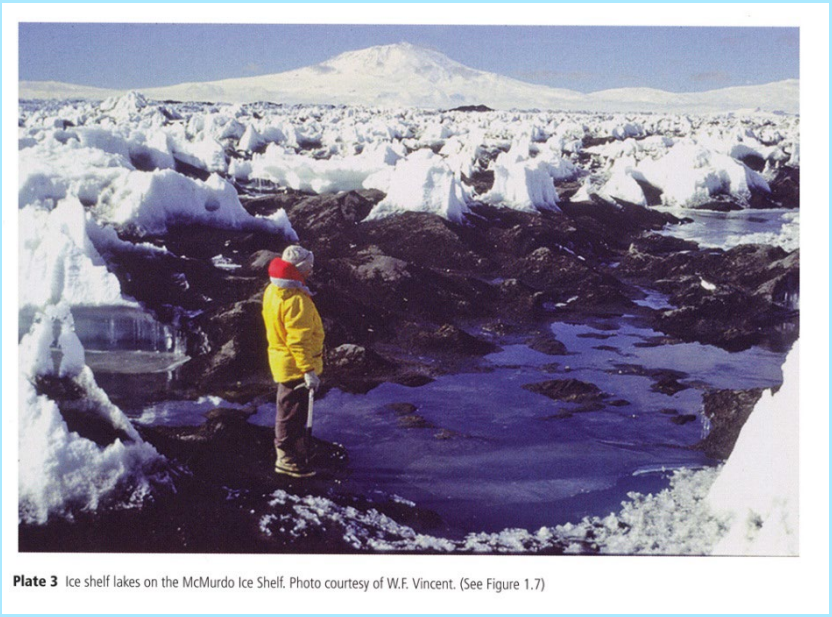


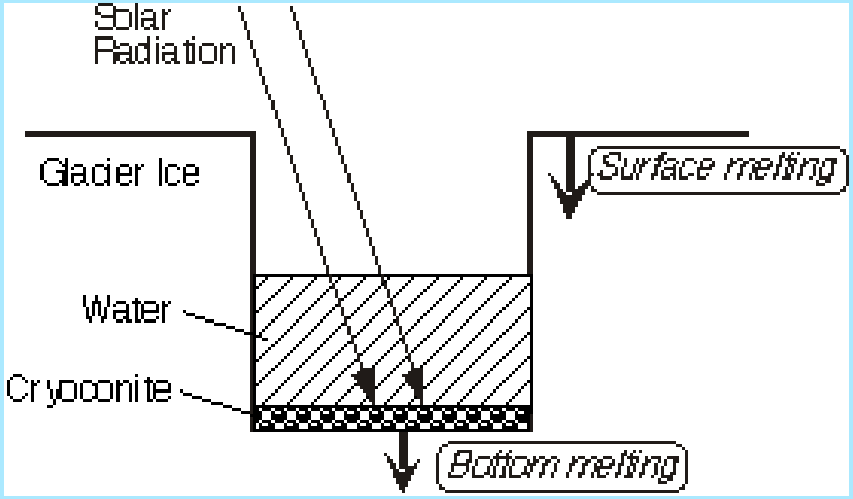
Plate 3 Ice shelf lakes on the McMurdo Ice Shelf. Photo courtesy of W.F. Vincent. (See Figure 1.7)

Plate 2 Cryolake on Canada Glacier, Taylor Valley. Photo courtesy of M. Tranter. (See Figure 1.6)

From Laybourn-Parry and Wadham. 2014. Antarctic Lakes. Oxford Univ. Press

https://en.wikipedia.org/wiki/Cryoconite

Cryoconite holes form from wind blown dust, soot, microbes on glacial surface, dark color absorbs heat and melts ice below



http://www-es.s.chiba-u.ac.jp/~takeuchi/cryoconite.html

Subglacial Lakes

Hundreds now known
Most small, less than 10 km in length
First discovered in 1960s using radio-echo sounding
Isolated from the atmosphere for millions of years

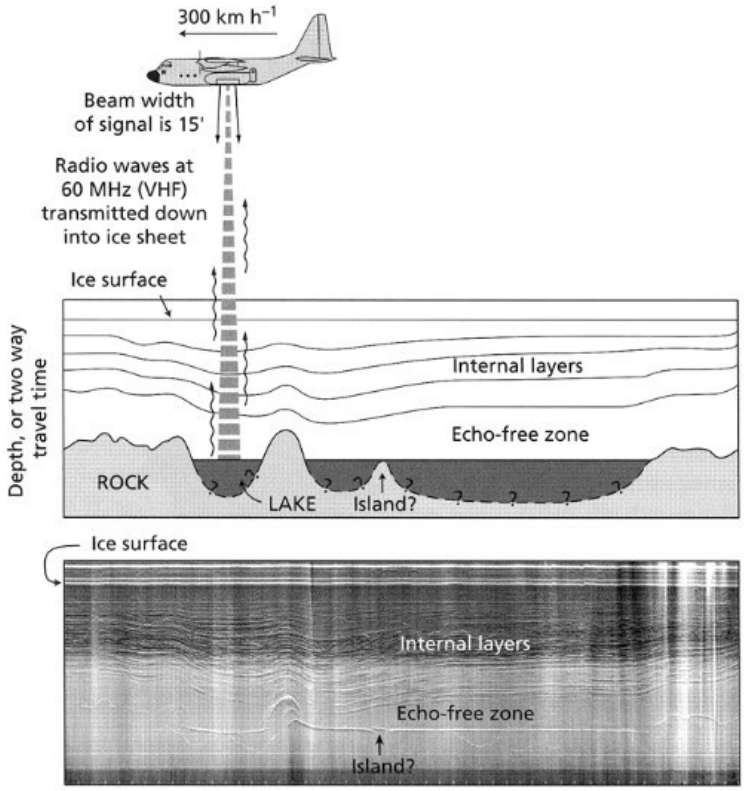


Figure 6.2 Diagrammatic explanation of the application of radio-echo sounding to the identification of Subglacial Lake Vostok and other lakes. Subglacial lakes can be easily identified in these data by their uniformly strong and flat appearance. Bed-rock reflections show as hyperbolae in these data (Siegert et al. 2001). With the permission of Nature Publishing Group.

From Laybourn-Parry and Wadham. 2014. Antarctic Lakes. Oxford Univ. Press

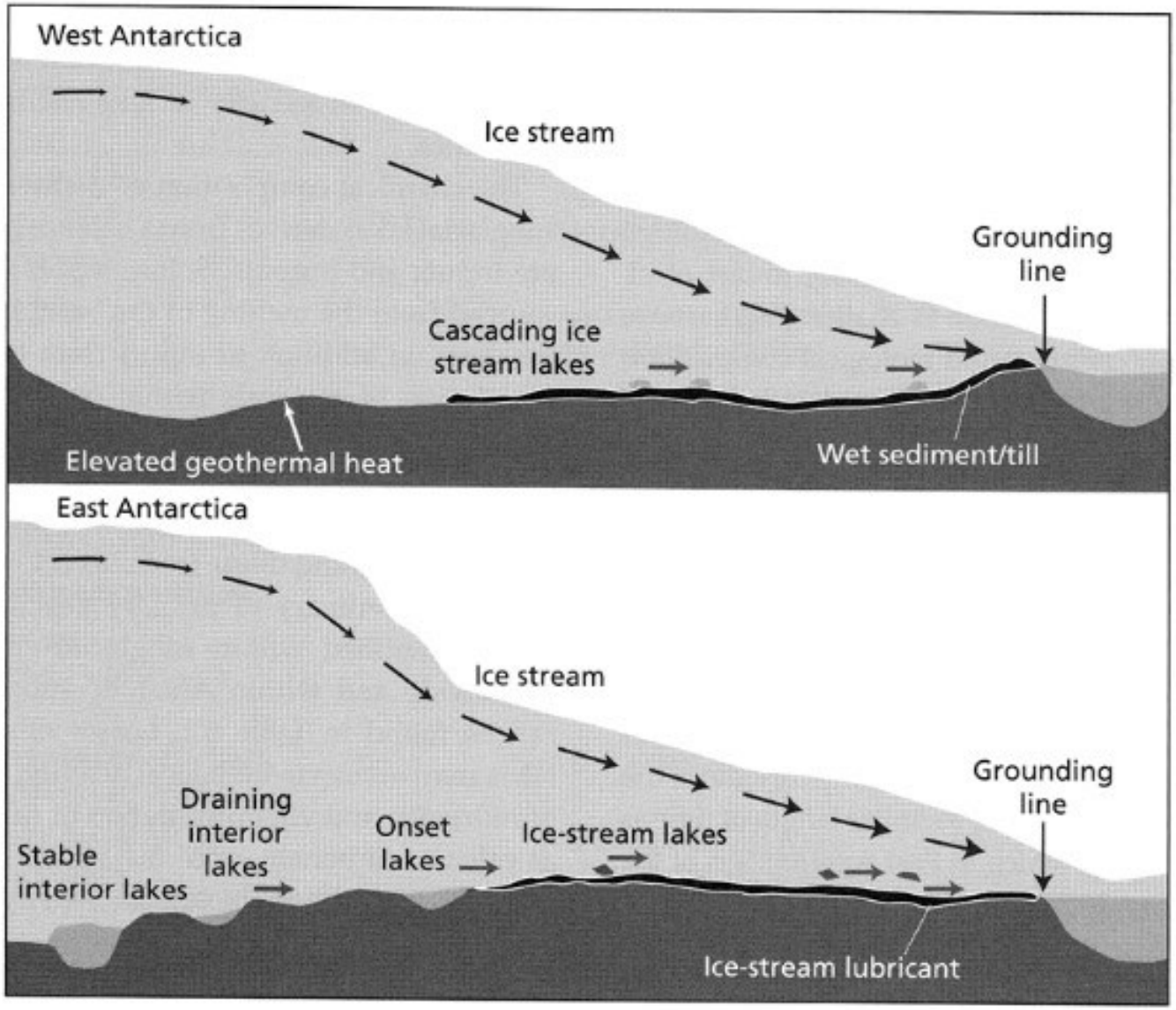
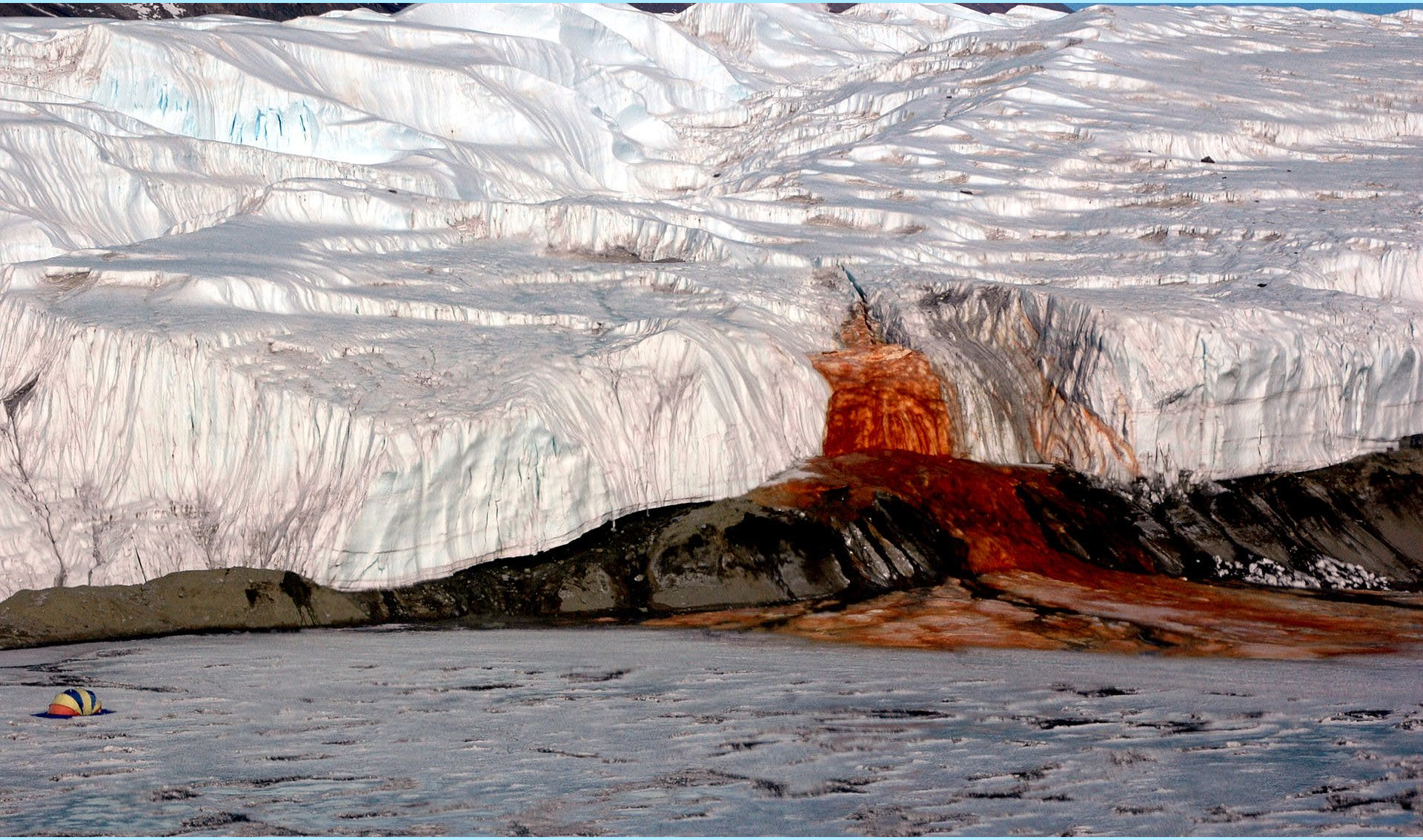


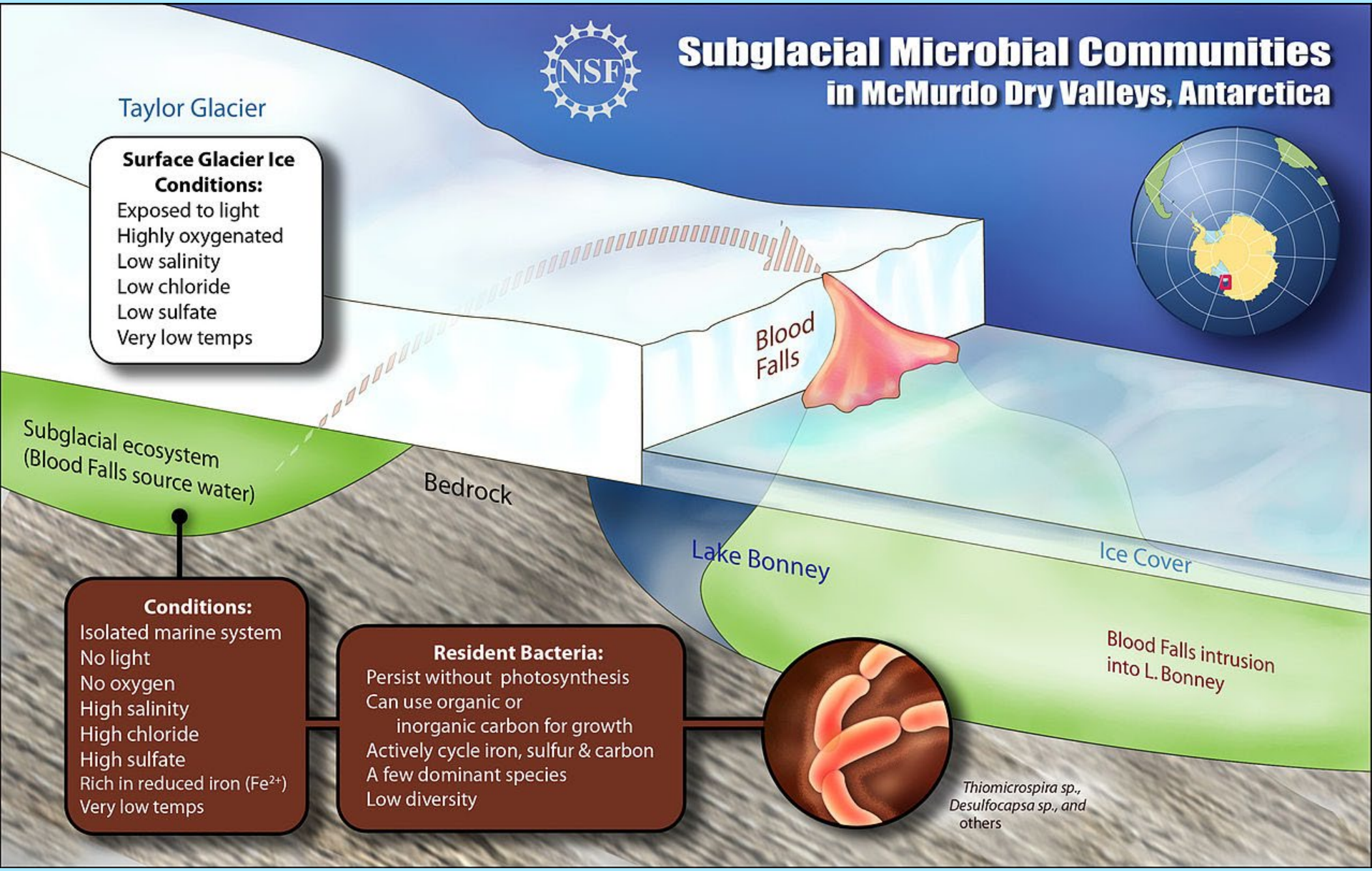
Figure 6.7 Conceptual model of the distribution of liquid water beneath the West and East Antarctic Ice Sheets (Bell 2008). With the permission of Nature Publishing Group.

From Laybourn-Parry and Wadham. 2014. Antarctic Lakes. Oxford Univ. Press

Blood Falls, Taylor Valley

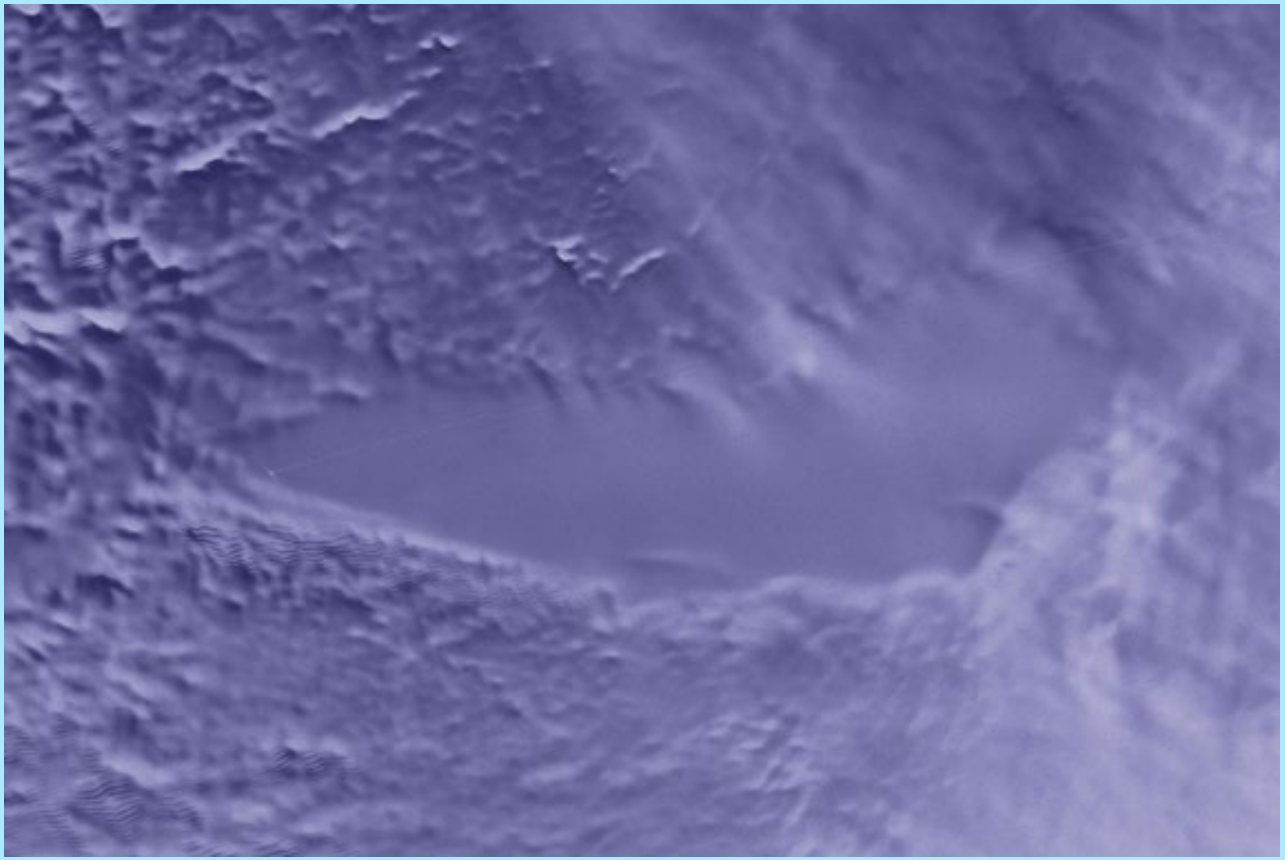


https://en.wikipedia.org/wiki/Blood_Falls


Subglacial Microbial Communities
in McMurdo Dry Valleys, Antarctica
NSF
Taylor Glacier
Surface Glacier Ice Conditions:
Exposed to light
Highly oxygenated
Low salinity
Low chloride
Low sulfate
Very low temps
Blood Falls
Subglacial ecosystem (Blood Falls source water)
Bedrock
Lake Bonney
Ice Cover
Blood Falls intrusion into L. Bonney
Conditions:
Isolated marine system
No light
No oxygen
High salinity
High chloride
High sulfate
Rich in reduced iron (Fe^{2+})
Very low temps
Resident Bacteria:
Persist without photosynthesis
Can use organic or inorganic carbon for growth
Actively cycle iron, sulfur & carbon
A few dominant species
Low diversity
Thiomicrospira sp., Desulfocapsa sp., and others

Lake Vostok

Largest and best known lake, 250 x 50 km
Estimated sediment record of 300-400 m on lake floor
Has not been exposed to the atmosphere for 14 Ma



Radarsat image of lake below ice

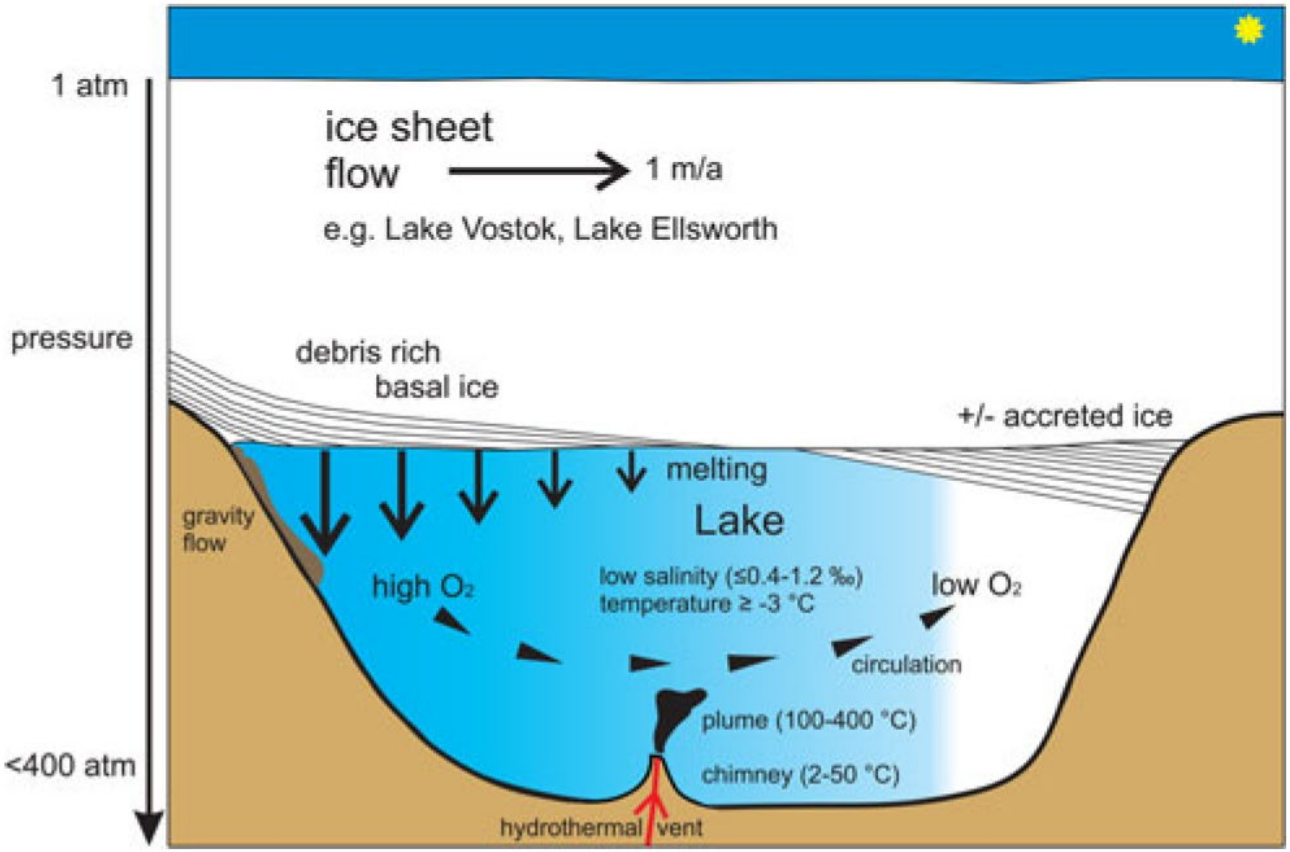


Fig. 1. Schematic representation of the physico-chemical conditions potentially found in a stable subglacial lake. Modified after Bentley *et al.* (2011). Melting of basal ice releases oxygen, leading to circulation within the lake. Areas of low oxygen most likely prevail in areas of ice accretion. Under the high-pressure conditions found, water temperature reaches exceptionally low levels for a liquid water body.

From Thatje et al. (2019)

Russians cored into lake in 2013, but rising water in bore hole froze, samples contaminated

Thousands of microbes were in accreted ice just above lake, but contamination is possible

Drilled a new bore hole and reached liquid water in January 2015

First results in Bulat (2017)

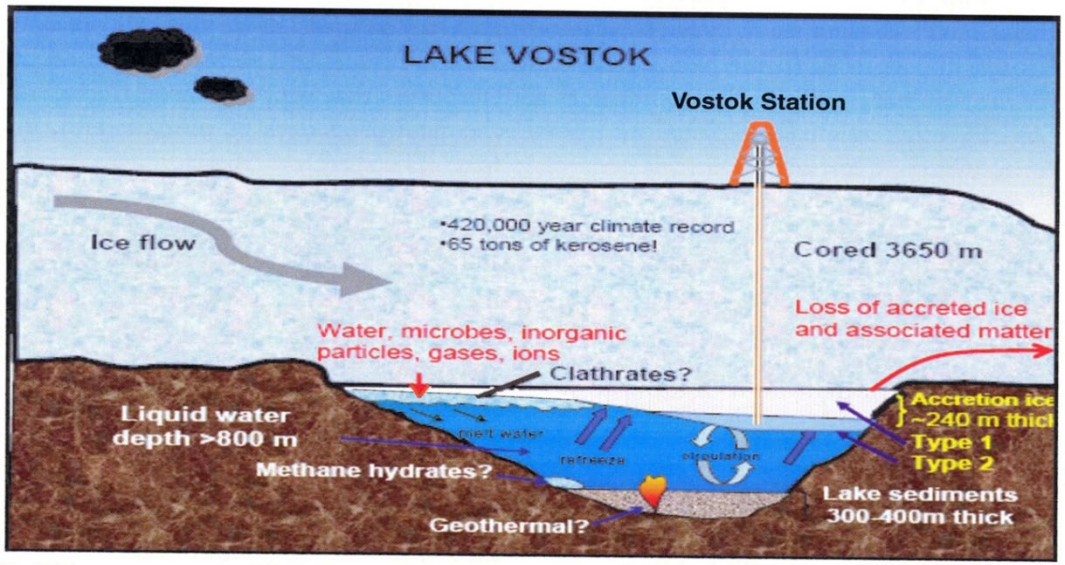


FIGURE S.2 Conceptual representation of processes likely occurring in Lake Vostok. Russian Antarctic Program drilling has penetrated through the ice sheet and into ice refrozen from lake water. Drilling of an additional 75 m is planned for the summer Antarctic season 2007/2008. No details regarding exact ice flow directions or areas of ice accretion are intended. Adapted from SCAR 2006, *http://salepo.tamu.edu/scar_sale/presentation*). SOURCE: John C. Priscu, Montana State University.

Quiz

1. Why are many Antarctic lakes considered to be ultra-oligotrophic?

2. What plant and animal life is found in Antarctic freshwater lakes?

3. What is Lake Washburn and how does it relate to current lakes in the Dry Valleys?

4. What is Blood Falls and how did it form?

5. What is significant about Lake Vostok that makes it unique?